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Factors affecting commercial energy consumption in Pakistan: Progress in energy

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ABSTRACT

The purpose of this study is to identify major macroeconomic factors that enhance energy consumption for Pakistan through the cointegration, error correction model and Granger causality tests over a 32-year time period, i.e., between 1980 and 2011. The study employed the bivariate cointegration technique to estimate the long-run relationship between the variables; an error correction model was used to determine the short-run dynamics of the system, while Granger causality test was used to find the directions between these variables. The study investigates the relation between four energy consumption variables (i.e., oil/petroleum consumption, gas consumption, electricity consumption and coal consumption) and four macroeconomic factors which have further sub-classifications, i.e., balance of payment (BOP) factors (i.e., exports, imports, trade deficit, worker's remittances and current account balance), fuel factors (i.e., carbon dioxide emissions, natural resource depletion and net forest depletion), agricultural crops yield per hectare (i.e., wheat, rice, sugarcane, maize and cotton) and industrial production items (i.e., beverages, cigarettes, motor tyres, motor tubes, cycle tyres and cycle tubes) in order to manage robust data analysis. The result confirms the long-run relationship between total commercial energy consumption and macroeconomic factors in Pakistan, as oil/petroleum consumption increases exports, fuel factors, agricultural crops yield per hectare and industrial items; however, the intensity of these factors are different in nature. Carbon dioxide emissions, net forest depletion, beverages, motor tyres and motor tubes are more elastic with oil/petroleum consumption. However, oil/petroleum consumption decreases trade deficit and workers' remittances in Pakistan. Gas, electricity and coal consumption increases agricultural crops yield per hectare and industrial production which shows that as agriculture and industry modernizes, energy demand increases. Energizing the food production chain is an essential feature of agricultural development which is a prime factor in helping to achieve food security in Pakistan. The empirical results only moderately support the conventional view that energy consumption has significant long-run casual effect on macroeconomic variables in Pakistan. The present study finds evident of unidirectional causality between the commercial energy consumption factors and macroeconomic factors in Pakistan. However, there is some bidirectional causality exist which is running between electricity consumption (EC) and exports, EC to imports, EC to carbon emissions, EC to natural resource depletion (NRD) and EC to wheat. The results conclude that macroeconomic variables tend to positively respond to total primary energy consumption. This indicates that increasing total commercial energy consumption may cause growth variables which show that Pakistan is an input-driven economy.

Contents

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1. Introduction

Energy indicators can play an important role in supporting energy efficiency policy development and evaluation. Accelerating energy efficiency improvements is a crucial challenge for energy and climate policies. The rate of energy efficiency improvement needs to be increased substantially to achieve a more secure and sustainable energy future [70]. According to HES [41, p. 2],

> "Faced with an economic crisis, along with the challenges posed by climate change, increasing import dependency and the rise in fossil fuel prices, we must find an immediate solution for conserving economic and social livelihoods while maintaining a balanced ecological system. By promoting renewable energy technologies, we are able to tackle both security of supply and climate change, while creating sustainable economy".

Energy is consumed in the industrial sector by a diverse group of industries including manufacturing, agriculture, mining, and construction—and for a wide range of activities, such as processing and assembly, space conditioning and lighting. The industrial sector consumed 52% of global delivered energy in 2008, and its energy consumption grows by an average of 1.5% per year over the projection. Industrial energy demand varies across regions and countries of the world, based on the level and mix of economic activity and technological development, among other factors. Industrial energy use also includes natural gas and petroleum products used as feedstocks to produce non-energy products, such as plastics and fertilizer [44].

The radical changes in energy prices since 1973 are likely to have significant effects upon the composition of energy use in developing countries. Although there have been major fuel substitution cycles in the past – of wood by coal and coal by oil – the nature of this process is not well understood [24].

According to Martınez and Ebenhack [65, p. 1431],

> "…. 'energy-poor' nations seeking to improve their quality of life will need increased access to cleaner, more reliable and efficient energy sources. Thus, it follows that part of global energy transition planning entails reasonable evaluation of the goals society should set to address the imperative of increasing energy access to people seeking to improve their current conditions".

The amount of energy used in agricultural production, processing and distribution is significantly high. Sufficient supply of the right amount of energy and its effective and efficient use are necessary for an improved agricultural production. It has been realized that crop yields and food supplies are directly linked to energy [84]. Land use changes and continuous use of fossil fuels that took place during the last century are some of the most important activities responsible for the increase of greenhouse gasses (GHGs) and subsequently climate change [93]. Carbon dioxide is one of the most important GHGs being among the most efficient long wave radiation absorbers and among the most abundantly emitted ones by natural and anthropogenic sources [5]. Kebedea et al. [53] conclude that factors that contribute to sustainable development include access to an affordable and efficient energy supply, reliable and mixed energy sources, reduced reliance on traditional fuels, and emphasis on renewable, sustainable sources of energy (e.g., biomass, solar, wind and geothermal).

The rise in global energy demand has raised questions regarding energy security and increased the focus on diversification, generation and efficient allocation. The answer lies in the attainment of optimal energy mix through fuel substitution by promoting energy efficiency and renewable energy and interregional co-operation. However, oil and natural gas will continue to be the world's top two energy sources through 2040, accounting for about 60% of global demand. Gas being the fastest growing major fuel source over this period is expected to grow at 1.6% per year from 2010 to 2040 [32].

Energy is considered to be the lifeline of economic development. For a developing economy with a high population growth rate, it is important to keep a balance between energy supply and emerging needs. If corrective measures are not effectively anticipated significant constraints start emerging for development activities [77]. Pakistan's economy has been growing at an average growth rate of almost 3% for the last four years and demand of energy at both production and consumer end is increasing rapidly. Knowing that there is a strong relationship between economic growth and energy demand, the government is making all possible efforts to address the challenges of rising energy demand [54]. The agriculture sector of Pakistan recorded a growth of 3.1% against 2.4% last year. The large scale manufacturing (LSM) growth is 1.1% during 2011–2012 against 1.0% last year. Overall, the commodity producing sectors and especially the agriculture sector have performed better. The services sector recorded growth of 4.0% in 2011–2012 [32].

During 2011–2012, energy outages in Pakistan continued to be the dominant constraint in its growth. Yet, traces of energy supply shortages can be traced to the independence of the country. Till the 1980s, less than two-thirds of the energy requirements were met through its own domestic resources. In the 1990s, Pakistan was still engaged in various efforts to bridge the wide gap between increasing demand and limited energy supply [49].

Further in the early 2000s, the energy sector (especially its sub-sector electricity) received greater attention because of the faster rate of growth in its demand. By 2011–2012, electricity and gas shortages are considered to be the primary cause of constrained production activities in a number of industries. Energy intensive industries (Petroleum, Iron and Steel, Engineering Industries and Electrical) shaved off 0.2% points from real GDP growth in 2010–2011 and in 2011–2012. Also, the estimated cost of power crises to the economy is approximately Rs.380 billion per year, around 2% of GDP, while the cost of subsidies given to the power sector to the exchequer in the last four years (2008–2012) is almost 2.5% of GDP (Rs. 1100 billion). The liquidity crunch in the power sector has resulted in under utilization of installed capacity of up to 4000 MW. It has also affected investment in power sector [32].

Pakistan has huge coal reserves which are estimated at over 185 billion tons; including 175 billion tons identified at Thar coalfields in Sindh province. Pakistan's coal generally ranks from lignite to sub-bituminous. The total production of coal during 2010–2011 was 7.7 million tons as compared to 8.1 million tons in 2009–2010; showing a negative growth of 5.1%. In 2010–2011 the import of coal was 4267 million tons compared to 4658 million tons in 2009–2010; a decline of 8.4%. The long trend shows that there was an increase of production of coal; an average 7.7% change occurred in last ten years [33]. Table 1 shows the production of coal in Pakistan during the period of 2006–2011.

The contribution of Hydel in electricity generation in Pakistan increased to 33.6% in 2011. Karachi Electricity Supply Corporation (KESC) contributed 8.3%, Pakistan Atomic Energy Commission (PAEC) 3.6%, Kot Addu Power Company (KAPCO) 6.2, and the Hub Power Company (HUBCO) 9.1% to total electricity generation. Independent power producers (IPPs) have contributed almost 25%. The Government is implementing a number of priority hydel projects such as 969 MW-Neelum Jhelum, 1410 MW-Tarbela 4th Extension, and Patrind in the private sector. Almost 96% of the work on the main dam at Mangla, spillway and allied facilities are completed and resettlement work is in progress. Likewise 99.7% work on Satpara and 72.1% on Gomal Zam dam have been completed. 7100 MW-Bunji, 4320 MW-Dasu, 80 MW Kurram Tungi Dam, 740-MW Munda Dam and 4500 MW-Diamer Bhasha Dam are in the pipeline. Pakistan is one of the beneficiaries of Tetra-partner power import project under the head of Central Asia-South Asia (CASA-1000) electricity trade. In addition, a number of thermal projects are under implementation including 747 Guddu refurbishment [32].

1.1. Energy and trade components

Since the 1970s, trade liberalization and globalization are increasingly recognized as one of the development policies to boost economic growth [23]. Exports and economic growth are linked within an economic, social and physical structure where fossil fuel consumption is essential [85]. According to Jacobsen [46, p. 319],

Table 1
Production of coal, share and percentage change.
Source: Ref. [33].

Fiscal year	Imports		Domestic production		Total	
	Ton (000)	% Share	Ton (000)	% Share	Ton (000)	% Share
2005–2006	2843	36.9	4871	63.14	7714	−2.3
2006–2007	4251	53.9	3643	46.15	7894	2.3
2007–2008	5987	59.2	4124	40.79	10,111	28.1
2008–2009	4652	55.4	3738	44.55	8390	−17.0
2009–2010	4658	57.2	3481	42.77	8139	−3.0
2010–2011	4267	55.3	3450	44.71	7717	−5.2

> "Trade-induced changes in energy consumption have important implications for issues such as international distribution and regulation of energy consumption and emissions. It is shown that a structural change in foreign trade patterns can increase domestic energy demand. This is contrary, however, to what might be expected for a small industrialized country, which is presumed to export products that intensively use inputs of skilled manpower as well as research and development".

The electricity sector is among the most polluting sectors in many countries, particularly because of its intensive use of fossil fuels such as diesel, coal, among others. Fossil fuel energy is among the most important sources of greenhouse gases (GHGs) and according to the Intergovernmental Panel on Climate Change [45], changes in climatic conditions are expected as greenhouse gases (GHGs) accumulate.

The relationship between energy consumption and trade is an important topic to study for several reasons. If energy consumption is found to Granger cause trade, then any reductions in energy consumption, coming from say energy conservation polices designed to reduce greenhouse gas emissions, will reduce trade and lessen the benefits of trade. Energy conservation policies which reduce energy consumption will offset trade liberalization policies designed to promote economic growth. This places energy reduction policies at odds with trade liberalization policies. If unidirectional Granger causality is found to run from trade to energy consumption or no Granger causal relationship is found then energy reduction policies will not affect trade liberalization policies designed to increase economic growth [76].

The unfavorable global environment has slowed down the world output and trade volume during 2011; world output which grew by 5.3% in 2010 decelerated to 3.9% in 2011. This slowing down of the global economic activity has caused a sharp decline in the growth of world trade. Against the strong pick up of nearly 13.0% in 2010 the growth of world trade dropped to 5.8% in 2011. The global economic slowdown and consequential decline in the growth of world trade has also depressed the international commodity prices. The prices of non-fuel commodities witnessed a deceleration from 26.3% in 2010 to 17.8% in 2011, and are projected to grow negatively by 10.3% in 2012 [32]. Amid the difficult global economic environment, the slowing down of the world trade, the drop in international commodity prices and the energy shortages domestically, Pakistan's exports growth would have been in much better position had there been normalization in international prospects during the period. In fiscal year 2011–2012, workers' remittances grew by $ 1.83 billion over the last year. The trade deficit expanded mainly due to the 14.5% growth in imports and the 0.1% increase in exports; thereby widening the trade deficit by 49.2% during the period. The major factor behind the widening of the trade deficit was the sharp rise in the import bill during July–April 2011–2012 which increased due to the higher international prices of crude oil [32]. Table 2 shows the summary of balance of payment in Pakistan during 2010–2012.

1.2. Energy and fuel factors

Linking energy issues to environmental concerns provided additional room for the strategic maneuvering of those actors that sought to achieve further policy integration and harmonization [87]. The emissions from the production of electricity are much greater than for the production of other fuels. However, electric vehicles produce no emissions at the point of use, so the actual environmental impact of electricity emissions (usually in rural areas) may be substantially lower than the impact of

Table 2
Summary of balance of payments (US $ million).
Source: Ref. [32].

Items	July–June		July–April[a]	
	2000–2010	2010–2011	2010–2011	2011–2012
Current account balance	−3946	214	466	−3394
Trade balance	−11,536	−10,516	−8499	−12,683
Service balance	−1690	−1940	−1225	−2347
Income account balance	−3282	−3017	−2465	−2655
Current transfers net	12,562	15,687	12,655	14,291
Capital and financial account	5272	2262	777	1367
Net errors and omissions	−60	16	−29	−515
Overall balance	1266	2492	1209	−2542

[a] Provisional.

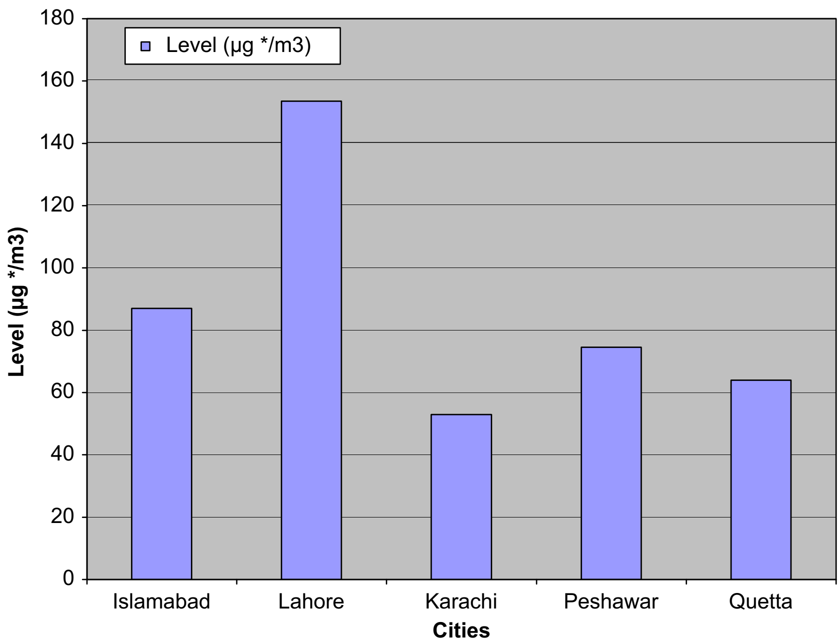

Fig. 1. Annual mean value of suspended particular material (PM 2.5) from June 2011 to March 2012.
Source: Ref. [32].

equivalent internal combustion engine emissions in more densely populated areas [61].

The quality of the natural environment is not only an extremely important issue from the point of view of individual survival but it will also emerge as one of the principal human security issues in Pakistan. The environmental challenges include climate change impacts, loss of biological diversity, deforestation and degradation of air and water quality. The fast growing population poses a significant challenge for Pakistan. The existing environment management capacity cannot sustain such a large population with a good quality of life [33]. Ambient air quality data recorded by real time automatic monitoring stations in the five capital cities of Pakistan confirmed the presence of high concentration of suspended particulate matter which is shown in Fig. 1.

1.3. Energy and agriculture

Energy has a key role in economic and social development but there is a general lack of rural energy development policies that focus on agriculture. Agriculture has a dual role as an energy user and as an energy supplier in the form of bioenergy. This energy function of agriculture offers important rural development opportunities as well as one means of climate change mitigation by substituting bioenergy for fossil fuels [27].

Table 3
Agricultural crops yield per hectare (kg/ha).
Source: Ref. [32].

Year	Cotton	Sugarcane	Rice	Wheat
2007–2008	649	51507	2212	2451
2008–2009	713	48635	2346	2657
2009–2010	707	52357	2387	2553
2010–2011	724	55981	2039	2833
2011–2012	815	55486	2396	2714

The agriculture sector continues to be an essential component of Pakistan's economy. It currently contributes 21% to GDP. Agriculture generates productive employment opportunities for 45% of the country's labor force and 60% of the rural population depends upon this sector for its livelihood. It has a vital role in ensuring food security, generating overall economic growth, reducing poverty and the transforming towards industrialization [34]. The overall performance of agriculture sector exhibited a growth of 3.1% mainly due to positive growth in agriculture related sub-sectors, except minor crops. Major crops accounted for 31.9% of agricultural value added

and experienced a growth of 3.2% in fiscal year 2011–2012 with negative growth of 0.2% in 2011. The significant growth in major crops is contributed by rice, cotton and sugarcane by 27.7%, 18.6% and 4.9%, respectively. Table 3 shows the agricultural crops yield per hectare during 2007–2012.

1.4. Energy and industrial production

Economic and environmental pressures for energy and material efficiency have been increasing in the past few decades, resulting in noticeable advances in process and product design and in making waste more recyclable and reusable [72]. Energy efficiency is rising toward the top of many national agendas for a number of compelling reasons that are economic, environmental and inter-governmental in nature. As many industries are energy-intensive, this is resulting in new impetus to industrial energy efficiency policies [96]. Manufacturing industry accounts for about one-third of total energy use worldwide. Roughly three quarters of industrial energy use is related to the production of energy-intensive commodities such as ferrous and non-ferrous metals, chemicals and petrochemicals, non-metallic mineral materials, and pulp and paper. In these sectors, energy costs constitute a large proportion of total production costs; as a result, the scope to improve energy efficiency tends to be less in these most energy intensive sectors than in those sectors where energy costs form a smaller proportion of total costs, such as the buildings and transportation sectors. This limits the overall potential for carbon dioxide (CO_2) reductions through energy efficiency measures in industry to 15–30% on average [91].

Pakistan's Government remained focused on maintaining macroeconomic stability, growth, mobilizing domestic resources and increasing exports, balanced regional development and providing safety nets for the vulnerable groups. Despite numerous challenges, the economy performed better than many developed and developing economies in 2011–2012. These included sharp increase in fuel and commodity prices, recessionary trend globally and weak inflows. Domestically, economy was struck by heavy rains in Sindh and parts of Balochistan costing $ 3.7 billion. Notwithstanding these challenges, the gross domestic product growth this year is estimated at 3.7% as compared to 3.0% last year. The growth of the manufacturing sector is estimated at 3.6% compared to 3.1% last year. Small scale manufacturing maintained its growth of last year at 7.5% and slaughtering growth is estimated at 4.5% against 4.4% last year. Large scale manufacturing (LSM) has shown a growth of 1.1% during July–March 2011–2012 against 1.0% last year. The construction sector has shown 6.5% growth as compared to negative growth of 7.1% last year. Mining and Quarrying sector recorded a positive growth of 4.4% during July–March of the fiscal year 2011–2012 against negative growth of 1.3% last year. Electricity and gas distribution witnessed a negative growth of 1.6% against −7.3% last year [32]. Table 4 shows the growth of different industrial items during 2011 and 2012.

Table 4
Group-wise growth for the month of July–March 2011-–2012 vs July–March 2010–2011.
Source: GoP [32].

Groups	% change July–March	
	2010–2011	2011–2012
Textile	0.7	0.8
Food, beverages and tobacco	14.0	6.5
Coke and petroleum products	−4.6	−5.7
Pharmaceuticals	1.3	10.9
Chemicals	−2.5	−4.7
Automobiles	11.9	−0.8
Iron and steel	−10.3	−28.5
Fertilizers	−9.2	−0.4
Electronics	−14.4	−7.9
Leather products	17.4	1.8
Paper and board	−2.3	8.4
Engineering products	−9.5	−10.2
Rubber products	9.2	−24.6
Non-metallic mineral products	−9.6	2.9
Wood products	6.9	7.4

The above discussion confirms a strong linkage between aggregate commercial energy consumption and macroeconomic factors in Pakistan. In this paper an analysis has been carried out to find a statistical relationship between commercial energy consumption components and macroeconomic factors in Pakistan, using secondary data from 1980 to 2011. Present study used different indicators for total commercial energy consumption, i.e., oil/petroleum consumption (OPC), gas consumption (GC), electricity consumption (EC) and coal consumption (CC), while study used four macroeconomic factors which also consists of sub-factors, i.e., balance of payment factors (i.e., exports, imports, trade deficit, workers' remittances and current account deficit); fuel factors (i.e., carbon dioxide emission, net forest depletion and natural resource depletion); agricultural crops yield per hectare (i.e., wheat, rice, sugarcane, maize and cotton); and industrial items (i.e., beverages, cigarettes, motor tyres, motor tubes, cycle tyres and cycle tubes) in Pakistan.

The objectives of this study are to empirically investigate:

- Whether the statistical relationship between the economic factors and energy factors in Pakistan is unidirectional (i.e., economic factors affect/cause energy factors or energy factors affect/cause energy factors).
- Whether the statistical relationship between the economic factors and energy factors in Pakistan is bi-directional (i.e., economic factors affect/cause energy factors and energy factors affect/ cause energy factors).
- The two variables (economic factors and energy factors) do not influence each other (causality independent).

The overall objectives are accomplished by examining Granger causality between growth in energy factors and economic factor in Pakistan.

The paper is organized as follows. Section 2 discusses the literature review. Analytical framework is presented in Section 3. Data source and methodological framework are explained in Section 4. Empirical findings are presented in Section 5. The final section contains concluding remarks.

2. Literature review

Energy use plays a critical role in affecting regional and global environmental problems, such as acid precipitation and global climate change. Additionally, stringent environmental standards can have important impacts on energy activities. Consequently, there is a "dual determinism" between energy policy and environmental control. As global climate change problems receive increased attention, there are more intergovernmental conventions on energy-related environmental problem [62]. Enhanced energy efficiency occupies a central role in evaluating the efficacy and cost of climate change policies. Ultimately, total greenhouse gas (GHG) emissions are the product of population, economic activity per capita, energy use per unit of economic activity and the carbon intensity of energy used. Although greenhouse gas emissions can be limited by reducing economic activity, this option obviously has little appeal even to rich countries, let alone poor ones [47]. It is generally recognized that the energy including electricity plays a significant role in economic

development, not only because it enhances the productivity of capital, labor and other factors of production, but also that increased consumption of energy, particularly commercial energy like electricity signifying high economic status of a country [51]. According to Vera and Langlois [92, p.1141],

> "Energy is an essential factor in overall efforts to achieve sustainable development. Countries striving to this end are seeking to reassess their energy systems with a view toward planning energy programmes and strategies in line with sustainable development goals and objectives".

Energy plays a vital role in the economic development and social/national security. However, current patterns of energy supply and energy use are unsustainable because the environmental issues such as global warming and acid rain arise from the energy consumption [88]. Due to the growing pressure exerted on governments to mitigate carbon dioxide (CO_2) emissions in order to slow down the rate of climate change, many countries worry about the negative effect on economic growth caused by the restricted use of fossil fuels, especially by developing countries, that are mainly used to generate electricity and which give rise to large quantities of CO_2 emissions [18]. The use of renewable energy sources and the rational use of energy, in general, are the fundamental inputs for any responsible energy policy. However, the energy sector is encountering difficulties because increased production and consumption levels entail higher levels of pollution and eventually climate change, with possibly disastrous consequences. At the same time, it is important to secure energy at an acceptable cost in order to avoid negative impacts on economic growth [71].

2.1. Commercial energy consumption and balance of payments components nexus

Energy is a key factor in the determination of economic growth in modern economies. Individuals and organizations need different energy sources to ensure the sustainability of their businesses. It has also been proven that the energy sector, which includes electricity, plays a significant role in any economic development. This developmental effect can be felt not only on the improved labor and capital productivity due to a reliable energy sector but also by the fact that the consumption of electricity is a sign of good health of the economy in developing countries [57].

Lin and Polenske [63] conduct a structural decomposition analysis to explain China's energy use changes between 1981 and 1987. The results find that China's energy saving during this period came about primarily by changes in how to produce rather than changes in what to consume. The driving force of the energy intensity decline was energy efficiency improvements, which were multiplied across the entire economy through inter-industry input–output linkages. Suri and Chapman [86] examines the relationship between economic growth, trade and energy by using pooled cross-country and time-series data consists of observations on 33 countries over a 21-year period beginning in 1971 and ending in 1991. The results found that both industrializing and industrialized countries have added to their energy requirements by exporting manufactured goods, the growth has been substantially higher in the former. At the same time, industrialized countries have been able to reduce their energy requirements by importing manufactured goods. Exports of manufactured goods by industrialized countries have thus been an important factor in generating the upward sloping portion of the environmental Kuznets curve and imports by industrialized countries have contributed to the downward slope. Ang [6] examines the dynamic causal relationships between pollutant emissions, energy consumption, and output for France over the period of 1960–2000. The results support the argument that economic growth exerts a causal influence on growth of energy use and growth of pollution in the long run. The results also point to a unidirectional causality running from growth of energy use to output growth in the short run.

Halicioglu [37] empirically examines the dynamic causal relationships between carbon emissions, energy consumption, income and foreign trade in the case of Turkey using the time-series data for the period 1960–2005. The results suggest that income is the most significant variable in explaining the carbon emissions in Turkey which is followed by energy consumption and foreign trade. Moreover, there exists a stable carbon emissions function. Ahmed et al. [1] empirically examines the impact of remittances, exports, money supply on economic growth in the context of Pakistan over a period of 1976–2009. The result shows that remittances have a positive impact on economic growth of Pakistan in both the long run and short run. The short-run effect of remittances and exports are significant and contributing to about 0.034% and 0.078% to economic growth. However, money supply was found insignificant to contribute to growth. Hossain [42] examines the dynamic causal relationship between economic growth, electricity consumption, export values and remittance for the panel of three SAARC countries using the time series data for the period 1976–2009. The results support that there is only bidirectional short-run causal relationship between economic growth and export values but there is no evidence of long-run causal relationship. It is also found that the long-run elasticity of economic growth with respect to electricity consumption and remittance are higher than short-run elasticity. This shows that over time higher electricity consumption and higher remittance from manpower supply in the panel of SAARC countries give rise to more economic growth. Hussain et al. [43] examines the relationship among environmental pollution, economic growth and energy consumption per capita in the case of Pakistan over a period of 1971–2006. The Granger causality test shows that there is a long term relationship between these three indicators, with bidirectional causality between per capita CO_2 emission and per capita energy consumption. A monotonically increasing curve between GDP and CO_2 emission has been found for the sample period, rejecting the EKC relationship, implying that as per capita GDP increases a linear increase will be observed in per capita CO_2 emission. Zaman et al. [100] re-investigate the multivariate electricity consumption function for Pakistan, particularly, economic growth, foreign direct investment and population growth over a 36-year time period, i.e., between 1975 and 2010. The results reveal that determinants of electricity consumption function are cointegrated and influx of foreign direct investment, income and population growth is positively related to electricity consumption in Pakistan. However, the intensity of these determinants is different on electricity consumption. Dynamic short-run causality test indicates that there has been unidirectional causality which is running from population growth to electricity consumption in Pakistan. Ahmed and Long [2] investigate the relationship between CO_2 emission, economic growth, energy consumption, trade liberalization and population density in Pakistan with yearly data from 1971 to 2008. The result found that trade supports the environment positively and population contributes to environmental degradation in Pakistan.

2.2. Commercial energy consumption and fuel factors nexus

The rapid growth of energy use, worldwide, has already raised concerns over problems of supply, the exhaustion of energy resources and severe environmental impacts (ozone layer

depletion, global warming, climate change, etc.) [78]. Mansur et al. [64] estimates a US energy model of fuel choice by both households and firms by using cross-sectional data. The result shows that consumers in warmer locations rely relatively more heavily on electricity rather than natural gas, oil and other fuels. They also use more energy. Climate change likely increase electricity consumption on cooling but reduce the use of other fuels for heating. American energy expenditures likely increase, resulting in welfare damages that increase as temperatures rise. According to Davis and Caldeira [21, p.5687],

> "CO_2 emissions from the burning of fossil fuels are the primary cause of global warming. Much attention has been focused on the CO_2 directly emitted by each country, but relatively little attention has been paid to the amount of emissions associated with the consumption of goods and services in each country. Consumption-based accounting of CO_2 emissions differs from traditional, production-based inventories because of imports and exports of goods and services that, either directly or indirectly, involve CO_2 emissions".

Ghosh [31] examines carbon emissions economic growth nexus for India over a period of 1971–2206. The study fails to establish long-run equilibrium relationship and long term causality between carbon emissions and economic growth; however, there exists a bi-directional short-run causality between the two. The result further establishes unidirectional short-run causality running from economic growth to energy supply and energy supply to carbon emissions. Ang [7] examines the long-run relationship between output, pollutant emissions, and energy consumption in Malaysia during the period 1971–1999. The results indicate that pollution and energy use are positively related to output in the long-run. The study found a strong support for causality running from economic growth to energy consumption growth, both in the short-run and long-run. According to Hassan et al. [40, p. 1195],

> "Conversion of natural forests and woodlands is still the main strategy and source of land for agricultural expansion in most developing countries…. In addition to the rapid depletion of natural woodlands and forest resources, deforestation leads to increased desertification and destruction of the ecosystem. As a consequence, soil resources are degraded through high erosion and loss of nutrients leading to declining agricultural productivity on-site as well as downstream".

Brandt [17] explores the impact of oil depletion on the energetic efficiency of oil extraction and refining in California. Results indicate that the energy intensity of oil extraction in California increased significantly from 1955 to 2005. This resulted in a decline in the life-cycle EROI from ≈ 6.5 to ≈ 3.5 (measured as megajoules (MJ) delivered to final consumers per MJ primary energy invested in energy extraction, transport and refining). Most of this decline in energy returns is due to increasing need for steam-based thermal enhanced oil recovery, with secondary effects due to conventional resource depletion (e.g., increased water cut).

According to Khan and Latif [55, p. 2179],

> "Like many other developing countries of the world, Pakistan is also energy deficient country. Since last few decades, its electricity generation has become dependent to a large extent on the petroleum fuels. The inevitable depletion of petroleum resources will have far reaching consequences on large scale development for future, unless renewable energy alternation can be found".

Nasir and Rehman [68] investigate the relationship between carbon emissions, income, energy consumption and foreign trade in Pakistan for the period 1972–2008. The result shows that there is a quadratic long-run relationship between carbon emissions and income, confirming the existence of Environmental Kuznets Curve for Pakistan. Moreover, both energy consumption and foreign trade are found to have positive effects on emissions. The short-run results have, however, denied the existence of the Environmental Kuznets Curve. According to Ali and Nitivattananon [4, p.775],

> "Population of two cities in Pakistan has already crossed the 10-million figure and for the rest of the areas in the country populations are also increasing rapidly. Urbanization has boosted the use of energy in the cities and so is greenhouse gas (GHG) emissions but the ground situation as to the extent, vulnerability, past trends and future scenarios are not unveiled for the cities of Pakistan".

Jan [48] provides empirical evidence of individual, household and community level variables that play a vital role in the adoption of improved cookstoves, based on primary data collected from 100 randomly selected households in two villages of rural northwest Pakistan. The result depicts that education and household income are the most significant factors that determine a household willingness to adopt improved biomass stoves. The study concludes that the rate of adoption could substantially be improved if the government and non-governmental organizations (NGOs) play a greater role in overcoming the social, economic, cultural, political, and institutional barriers to adopting improved cooking technologies.

2.3. Commercial energy consumption and agricultural production nexus

According to Fraiture et al. [28, p. 67],

> "Rising energy prices, geopolitics and concerns over the impact of greenhouse gas emissions on climate change are increasing the demand for biofuel production. At present biofuel production is estimated at 35 billion liters, accounting only for a small part (2%) of the 1200 billion liters of annual gasoline consumption worldwide. But the contribution of biofuels to energy supply is expected to grow fast with beneficial impacts including reductions in greenhouse gasses, improved energy security and new income sources for farmers. However, biomass production for energy will also compete with food crops for scarce land and water resources, already a major constraint on agricultural production in many parts of the world".

Komleh et al. [56] examine energy consumption patterns in different sizes of farms for corn silage production, collected data from 40 producers, using face to face questionnaire method in Karaj city. The survey studies indicated that the most important energy inputs were machinery and chemical fertilizers with 42% and 28% of total energy input, respectively. The total consumption energy was 68,928 MJ ha^{-1} where the output was 148,380 MJ ha^{-1}. The results showed that farms with more than 10 ha use the least amount of total energy per hectare. The energy ratio, energy productivity, specific energy and net energy were 2.27, 0.28 kg MJ^{-1}, 3.76 MJ kg^{-1} and 79,452 MJ ha^{-1}, respectively. Share of direct and indirect energy was 25% and 75%, respectively. Akdemir et al. [3] examine the energy use patterns and energy input–output analysis of apple production in the Antalya province, Turkey, data collected from 90 apple farms by using a face-to-face survey method. The result shows that apple production consumed a total of 43,404.31 MJ ha^{-1}. The energy ratio for apple was estimated to be 1.51. The specific energy, energy productivity, energy intensiveness and net energy yield were 1.59 MJ kg^{-1}, 0.63 kg MJ^{-1}, 3.31 MJ TL^{-1} and 22,103.83 MJ ha^{-1},

respectively. The non-renewable form of energy input was 95.76% of the total energy input used in apple production compared to only 4.01% for the renewable form. The benefit cost ratio of the cotton production was 1.48. According to [15],

> "Energy plays a pivotal role in socio-economic development by raising standard of living. It is becoming gradually accepted that current energy systems, networks encompassing every thing from primary energy sources to final energy services, are becoming unsustainable. Development of conventional forms of energy for meeting the growing energy needs of society at a reasonable cost is the responsibility of the Governments".

Zaman et al. [101] investigate the casual relationship between energy consumption and agricultural technology factors, in the agricultural sector of Pakistan over a period of 1975–2010. The results infer that tractor and energy demand have bi-directional relationship; while irrigated agricultural land, share of agriculture and industry value added and subsides have supported the conventional view, i.e., agricultural technology cause energy consumption in Pakistan. On the other hand, neither fertilizer consumption and high technology exports nor energy demand affect each others. Zaman et al. [102] examine the long-run relationship between water resources and specific growth factors (energy consumption, water availability in agriculture, agriculture value added, urbanization, population and trade openness) in Pakistan, over a period of 1975–2009. The result shows that energy consumption and agriculture value added are positive related to water availability (environmental factor) both in the short and long-run. Increase in urbanization is the major contributor to environmental damages (water availability). Population has a significant impact on water availability in the short-run; however, it is insignificant in the long-run. Trade openness has a negative impact on water recourses in the long-run. Zaman et al. [103] investigate the influence of agricultural technologies on carbon emissions in Pakistan by using annual data from 1975 to 2010. Results indicate that unidirectional causality runs from agriculture machinery to carbon emissions but not vice versa. Agricultural technologies are closely associated with economic growth and carbon emissions in Pakistan. Variance decomposition analysis shows that among all the agricultural technologies, granting subsidies to the agriculture sector have exerts the largest contribution to changes in carbon emissions. Conversely, agricultural irrigated land seems relatively the least contributors on changes in carbon emissions due to infertility of total irrigated land available in Pakistan.

2.4. Commercial energy consumption and industrial production nexus

Energy plays a unique role in the supply chain as it is both a final good for end-users as well as an input into the production processes of many businesses. The decisions households and businesses must make regarding energy use are influenced by, and have implications for, short-run changes in economic activity as well as longer term trends [79]. Bowden and Payne [16] examine the causal relationship between energy consumption and real GDP using aggregate and sectoral primary energy consumption measures within a multivariate framework, by utilizes U.S. annual data from 1949 to 2006. The causality tests reveal that the relationship between energy consumption and real GDP is not uniform across sectors. Granger causality is absent between total and transportation primary energy consumption and real GDP, respectively. Bidirectional Granger causality is present between commercial and residential primary energy consumption and real GDP, respectively. Finally, the results indicate that industrial primary energy consumption Granger causes real GDP. Nash [67] reviews the European Commission's Communication on the sustainable consumption and production and sustainable industrial policy action plan which was introduced on July 16, 2008. The study examines the priority areas identified for action, the means adopted to improve energy and environmental performance of products as well as uptake by consumers. The study concludes that the absence of mandatory quantifiable targets and deadlines and a reliance on both cross-sectoral and multi-level relationships are likely to weaken the ability of the action plan's fundamental objective of decoupling economic growth from resource use. Apergis and Payne [10] examine the causal relationship between renewable energy consumption and economic growth for 80 countries within a multivariate panel framework over the period 1990–2007. The results of the panel cointegration test indicates there is a long-run equilibrium relationship between real gross domestic product, renewable energy consumption, real gross fixed capital formation, and the labor force with the respective coefficient estimates positive and statistically significant. The results from the panel error correction model reveal bidirectional causality between renewable energy consumption and economic growth in both the short-run and long-run.

According to Rongqin et al. [75],

> "In essence, the impact of human economic and energy activities on regional carbon cycle is largely achieved by changing the industrial space pattern. The alteration of industrial space structure and the regional differences will change the pattern of human energy consumption, and further affect the rate of regional carbon cycle".

Siddiqui et al. [82] explore the cost of unserved energy due to power outages in Pakistan which is started in 2007. The study is based on a survey conducted for four major industrial cities of Punjab, i.e., Gujrat, Faisalabad, Gujranwala, and Sialkot. The survey data reveal that employment has not suffered any significant drop due to alternative energy arrangements. These arrangements, nevertheless, have increased the production cost of the firms. Delays in the delivery of supply orders are also due to energy shortage. The study reports that the total industrial output loss varies between 12% and 37%, with Punjab as the major affected province. Shahbaz et al. [80] investigate the relationship between energy (renewable and nonrenewable) consumption and economic growth using Cobb–Douglas production function in case of Pakistan over the period of 1972–2011. The findings show that both renewable and nonrenewable energy consumption add in economic growth. Capital and labor are also important determinants of economic growth. The VECM Granger causality analysis validates the existence of feedback hypotheses between renewable energy consumption and economic growth, nonrenewable energy consumption and economic growth, economic growth and capital. Kumar and Shahbaz [60] examined the relationship between coal consumption and economic growth for Pakistan over the period 1971–2009. The growth elasticity with respect to coal consumption is positive and significant in Pakistan.

Previous studies have mainly addressed the relationship between limited growth factors and some forms of commercial energy consumption, while no specific studies in the literature further discuss the casual relation between key macroeconomic factors and total commercial energy consumption. This study make an efforts to fill up the gap of prior research studies and to examine the casual relation between foremost growth variables and total commercial energy consumption components in Pakistan's case, recognizing the significant role that energy plays on growth, Pakistan is focusing on their energy issues and is formulating energy policies. Pakistan is the thirty third (33rd)

largest country regarding energy consumption in the world in recent years. Pakistan is presently facing a serious energy crisis. Although Pakistan needs about 14,000–15,000 MW of electricity per day, it can produce only about 11,500 MW, thereby creating a shortfall of 3000–4000 MW per day. Despite a strong economic growth and rising demand for energy, no worthwhile steps have been taken to install new capacity for energy generation. As a result, "load-shedding" is common in Pakistan, which is almost entirely achieved through frequent power shutdowns. Energy shortage has left a negative impact on productive functioning of Pakistani industry, commerce and even daily lives of people [39]. Therefore, this study investigates the relation between four energy consumption variables (i.e., oil/petroleum consumption, gas consumption, electricity consumption and coal consumption) and four macroeconomic factors which have further sub-classifications, i.e., balance of payment (BOP) factors (i.e., exports, imports, trade deficit, worker's remittances and current account balance), fuel factors (i.e., carbon dioxide emissions, natural resource depletion and net forest depletion), agricultural crops yield per hectare (i.e., wheat, rice, sugarcane, maize and cotton) and industrial production items (i.e., beverages, cigarettes, motor tyres, motor tubes, cycle tyres and cycle tubes).

3. Analytical framework

Although economic theories do not explicitly state a relationship between energy consumption and economic growth, empirical investigation of it has been one of the most attractive areas of energy economics literature for the recent two decades. Since the seminal work of Kraft and Kraft [58], many studies have investigated the causal relationship between energy consumption and economic growth. Economic theories indicate implicitly existence of the relationship between energy use and economic growth. However, this does not necessarily imply a causal relationship between them. The direction, strength and stability of the relationship between energy consumption and GDP (gross domestic product) play a substantial role in designing the energy policies [98]. In the debate of the energy—GDP nexus, the most revealing argument is that energy is an essential input for production because other factors of production such as labor and capital cannot be used without it. Therefore, energy consumption is regarded to be a limiting factor to economic growth [100]. The second strand is based on the neutrality hypothesis, in which energy is neutral to economic growth. The reason of the neutrality of energy to economic growth comes from the fact that the cost of energy is very small as proportion to GDP. Moreover, the impact of energy consumption on economic growth will depend on the structure of the economy and the level of economic growth. As a result of economic growth, production structure is likely to shift towards service sectors, which are not energy intensive activities [83,22].

According to export-led growth hypothesis, there are a number of channels within trade theory to support the export-led growth hypothesis [12]. For example, export growth leads an increase in demand for the country's output or expansion in exports may promote specialization, which boost the productivity level or export promotion eliminate overvaluation of the domestic currency, or countries with high export/GDP ratios are more open to outside influences and generate externalities such as the incentive to innovate [99]. On the other hand, the competing hypothesis suggests that the trade expansion should be considered as a "handmaiden" successful growth rather than an autonomous engine of growth [59]. There is also potential for growth-led exports [11].

A conventional neo-classical one-sector aggregate production function which has been augmented by balance of payment factors (i.e., exports, imports, trade deficit and current account balance) and energy; fuel factors (i.e., CO_2, net forest depletion and natural resource depletion) and energy; agricultural crops yield per capita and energy; industrial items production and energy, as separate factors of production is expressed in linear econometric form as follows:

$$E_t = \alpha_0 + \alpha_1 (BOP)_t + \alpha_2 (FUEL)_t + \alpha_3 (AGR)_t + \alpha_4 (IND)_t + \varepsilon \quad (1)$$

where E_t is aggregate commercial energy consumption comprises oil/petroleum consumption; gas consumption, electricity consumption and coal consumption; BOP is balance of payment factors; FUEL is fuel factors; AGR is agricultural yield per hectare and IND is industrial items production and ε is the regression error term. Eq. (1) demonstrates that all variables are in their natural logarithms. Eq. (1) further extended in bivariate model, i.e., estimated a simple non-linear model which examines the impact of macro factors (i.e., components of BOP; fuel, agriculture and industry) on total primary energy consumption (i.e., oil/petroleum; gas; electricity and coal) in Pakistan, which has been specified as follows:

Model 1. Total commercial energy consumption (TCEC) and balance of payment (BOP) factors

(I) **Oil/petroleum consumption (OPC) and BOP**

$$\begin{aligned}
&\log(EXP) = \alpha_1 + \alpha_2 \log(OPC) + \mu \\
&\log(IMP) = \beta + B_{2_1} \log(OPC) + \mu \\
&\log(TDEF) = \gamma_1 + \gamma_2 \log(OPC) + \mu \\
&\log(WR) = \chi_1 + \chi_2 \log(OPC) + \mu \\
&\log(CAB) = \phi_1 + \phi_2 \log(OPC) + \mu
\end{aligned} \quad (2)$$

(II) **Gas consumption (GC) and BOP**

$$\begin{aligned}
&\log(EXP) = \alpha_1 + \alpha_2 \log(GC) + \mu \\
&\log(IMP) = \beta + B_{2_1} \log(GC) + \mu \\
&\log(TDEF) = \gamma_1 + \gamma_2 \log(GC) + \mu \\
&\log(WR) = \chi_1 + \chi_2 \log(GC) + \mu \\
&\log(CAB) = \phi_1 + \phi_2 \log(GC) + \mu
\end{aligned} \quad (3)$$

(III) **Electricity consumption (EC) and BOP**

$$\begin{aligned}
&\log(EXP) = \alpha_1 + \alpha_2 \log(EC) + \mu \\
&\log(IMP) = \beta + B_{2_1} \log(EC) + \mu \\
&\log(TDEF) = \gamma_1 + \gamma_2 \log(EC) + \mu \\
&\log(WR) = \chi_1 + \chi_2 \log(EC) + \mu \\
&\log(CAB) = \phi_1 + \phi_2 \log(EC) + \mu
\end{aligned} \quad (4)$$

(IV) **Coal consumption (CC) and BOP**

$$\begin{aligned}
&\log(EXP) = \alpha_1 + \alpha_2 \log(CC) + \mu \\
&\log(IMP) = \beta + B_{2_1} \log(CC) + \mu \\
&\log(TDEF) = \gamma_1 + \gamma_2 \log(CC) + \mu \\
&\log(WR) = \chi_1 + \chi_2 \log(CC) + \mu \\
&\log(CAB) = \phi_1 + \phi_2 \log(CC) + \mu
\end{aligned} \quad (5)$$

Model 11. Total commercial energy consumption (TCEC) and fuel (FUEL) factors

(I) **Oil/petroleum consumption (OPC) and FUEL**

$$\begin{aligned}
&\log(CO2) = \alpha_1 + \alpha_2 \log(OPC) + \mu \\
&\log(NRD) = \beta + B_{2_1} \log(OPC) + \mu \\
&\log(NFD) = \gamma_1 + \gamma_2 \log(OPC) + \mu
\end{aligned} \quad (6)$$

(II) **Gas consumption (GC) and FUEL**

$$\log(CO2) = \alpha_1 + \alpha_2 \log(GC) + \mu$$

$$\log(NRD) = \beta + B_{2_1} \ \log(GC) + \mu$$
$$\log(NFD) = \gamma_1 + \gamma_2 \ \log(GC) + \mu \tag{7}$$

(III) **Electricity consumption (EC) and FUEL**

$$\log(CO2) = \alpha_1 + \alpha_2 \ \log(EC) + \mu$$
$$\log(NRD) = \beta + B_{2_1} \ \log(EC) + \mu$$
$$\log(NFD) = \gamma_1 + \gamma_2 \ \log(EC) + \mu \tag{8}$$

(IV) **Coal consumption (CC) and FUEL**

$$\log(CO2) = \alpha_1 + \alpha_2 \ \log(CC) + \mu$$
$$\log(NRD) = \beta + B_{2_1} \ \log(CC) + \mu$$
$$\log(NFD) = \gamma_1 + \gamma_2 \ \log(CC) + \mu \tag{9}$$

Model 111. Total commercial energy consumption (TCEC) and agricultural crops yield per hectare (AGRI) factors

(I) **Oil/petroleum consumption (OPC) and AGRI**

$$\log(WHEAT) = \alpha_1 + \alpha_2 \ \log(OPC) + \mu$$
$$\log(RICE) = \beta + B_{2_1} \ \log(OPC) + \mu$$
$$\log(SUGAR) = \gamma_1 + \gamma_2 \ \log(OPC) + \mu$$
$$\log(MAIZE) = \chi_1 + \chi_2 \ \log(ELCPC) + \mu$$
$$\log(GRAIN) = \phi_1 + \phi_2 \ \log(ELCPC) + \mu$$
$$\log(COTTON) = \kappa_1 + \kappa_2 \ \log(ELCPC) + \mu \tag{10}$$

(II) **Gas consumption (GC) and AGRI**

$$\log(WHEAT) = \alpha_1 + \alpha_2 \ \log(GC) + \mu$$
$$\log(RICE) = \beta + B_{2_1} \ \log(GC) + \mu$$
$$\log(SUGAR) = \gamma_1 + \gamma_2 \ \log(GC) + \mu$$
$$\log(MAIZE) = \chi_1 + \chi_2 \ \log(GC) + \mu$$
$$\log(GRAIN) = \phi_1 + \phi_2 \ \log(GC) + \mu$$
$$\log(COTTON) = \kappa_1 + \kappa_2 \ \log(GC) + \mu \tag{11}$$

(III) **Electricity consumption (EC) and AGRI**

$$\log(WHEAT) = \alpha_1 + \alpha_2 \ \log(EC) + \mu$$
$$\log(RICE) = \beta + B_{2_1} \ \log(EC) + \mu$$
$$\log(SUGAR) = \gamma_1 + \gamma_2 \ \log(EC) + \mu$$
$$\log(MAIZE) = \chi_1 + \chi_2 \ \log(EC) + \mu$$
$$\log(GRAIN) = \phi_1 + \phi_2 \ \log(EC) + \mu$$
$$\log(COTTON) = \kappa_1 + \kappa_2 \ \log(EC) + \mu \tag{12}$$

(IV) **Coal consumption (CC) and AGRI**

$$\log(WHEAT) = \alpha_1 + \alpha_2 \ \log(CC) + \mu$$
$$\log(RICE) = \beta + B_{2_1} \ \log(CC) + \mu$$
$$\log(SUGAR) = \gamma_1 + \gamma_2 \ \log(CC) + \mu$$
$$\log(MAIZE) = \chi_1 + \chi_2 \ \log(CC) + \mu$$
$$\log(GRAIN) = \phi_1 + \phi_2 \ \log(CC) + \mu$$
$$\log(COTTON) = \kappa_1 + \kappa_2 \ \log(CC) + \mu \tag{13}$$

Model 1V. Total commercial energy consumption (TCEC) & industrial (IND) items

(I) **Oil/petroleum consumption (OPC) and IND**

$$\log(BEV) = \alpha_1 + \alpha_2 \ \log(OPC) + \mu$$
$$\log(CIG) = \beta + B_{2_1} \ \log(OPC) + \mu$$
$$\log(MT) = \gamma_1 + \gamma_2 \ \log(OPC) + \mu$$
$$\log(MTUBE) = \chi_1 + \chi_2 \ \log(OPC) + \mu$$
$$\log(CT) = \phi_1 + \phi_2 \ \log(OPC) + \mu$$
$$\log(CTUBE) = \kappa_1 + \kappa_2 \ \log(OPC) + \mu \tag{14}$$

(II) **Gas consumption (GC) and IND**

$$\log(BEV) = \alpha_1 + \alpha_2 \ \log(GC) + \mu$$
$$\log(CIG) = \beta + B_{2_1} \ \log(GC) + \mu$$
$$\log(MT) = \gamma_1 + \gamma_2 \ \log(GC) + \mu$$
$$\log(MTUBE) = \chi_1 + \chi_2 \ \log(GC) + \mu$$
$$\log(CT) = \phi_1 + \phi_2 \ \log(GC) + \mu$$
$$\log(CTUBE) = \kappa_1 + \kappa_2 \ \log(GC) + \mu \tag{15}$$

(III) **Electricity consumption (EC) and IND**

$$\log(BEV) = \alpha_1 + \alpha_2 \ \log(EC) + \mu$$
$$\log(CIG) = \beta + B_{2_1} \ \log(EC) + \mu$$
$$\log(MT) = \gamma_1 + \gamma_2 \ \log(EC) + \mu$$
$$\log(MTUBE) = \chi_1 + \chi_2 \ \log(EC) + \mu$$
$$\log(CT) = \phi_1 + \phi_2 \ \log(EC) + \mu$$
$$\log(CTUBE) = \kappa_1 + \kappa_2 \ \log(EC) + \mu \tag{16}$$

(IV) **Coal consumption (CC) and IND**

$$\log(BEV) = \alpha_1 + \alpha_2 \ \log(CC) + \mu$$
$$\log(CIG) = \beta + B_{2_1} \ \log(CC) + \mu$$
$$\log(MT) = \gamma_1 + \gamma_2 \ \log(CC) + \mu$$
$$\log(MTUBE) = \chi_1 + \chi_2 \ \log(CC) + \mu$$
$$\log(CT) = \phi_1 + \phi_2 \ \log(CC) + \mu$$
$$\log(CTUBE) = \kappa_1 + \kappa_2 \ \log(CC) + \mu \tag{17}$$

where

i. TCEC represents total commercial energy consumption (includes oil/petroleum; gas; electricity and coal consumption).
ii. BOP represents balance of payment (includes exports; imports; trade deficit; worker's remittances and current account balance),
iii. AGRI represents agriculture (includes wheat, rice, sugarcane, maize and cotton),
iv. IND represents industry (includes beverages, cigarettes, motor tyres, motor tubes, cycle tyres and cycle tubes),
v. FUEL represents fuel (includes carbon dioxide embosoms, natural resource depletions and net forest depletion),
vi. OPC represents oil/petroleum consumption [tons],
vii. GC represents gas consumption [mm cft],
viii. EC represents electricity consumption [kilowatt-hours (kWh)],
ix. CC represents coal consumption [000 metric tons],
x. EXP represents exports as percentage of GDP,
xi. IMP represents imports as percentage of GDP,
xii. TDEF represents trade deficit as percentage of GDP,
xiii. WR represents worker's remittances as percentage of GDP,
xiv. CAB represents current account balance as percentage of GDP,
xv. CO_2 represents carbon dioxide emissions (kton),
xvi. NRD represents natural resource depletion (% of GNI),
xvii. NFD represents net forest depletion (current US $),
xviii. WHEAT represents wheat in kg ha,
xix. RICE represents rice in kg ha,
xx. SUGAR represents sugarcane in kg ha,
xxi. MAIZE represents maize in kg ha,

xxii. COTTON represents cotton in kg ha,
xxiii. BEV represents beverages (000 doz. bottles),
xxiv. CIG represents cigarettes (million Nos.).
xxv. MT represents motor tyres (ooo Nos),
xxvi. MTUBE represents motor tubes (ooo Nos),
xxvii. CT represents cycle tyres (ooo Nos),
xxviii. CTUBE represents cycle tubes (ooo Nos),
xxix. 'log' represents natural logarithm
xxx. μ represents error term.

The consumption of conventional fossil fuel (especially coal and petroleum) and adoption of hydropower energy are inevitably accompanied by human activities that polluted and damaged the environment, and also exhausted the natural resources [89]. For estimating energy consumption and macroeconomic factors, bivariate cointegration technique has been used to evaluate short- and long-run relationship between them, proposed by Engle and Granger [25]. There is much discussion on the relationship between energy and economic factors. However, empirical support to show the relation between the two variables has mainly based either on direct observation of the data or on some parallel based analyses. Such approaches are clearly insufficient to classify the nature of the underlying linkage between energy and economics proxies. Moreover, such analyses failed to distinguish between four alternative but equally plausible hypotheses, each with different policy implications. These are: (i) economic factors cause energy factors; (ii) energy factors cause economic factors; (iii) there is a bi-directional causality between the two variables; and (iv) both variables are causality independent (although highly correlated). In the subsequent sections, an effort has been made to empirically find out the casual relationship between energy and economic factors in the context of Pakistan.

4. Data source and methodlogical framework

The study implies annual observations for the period of 1980–2011, i.e., 32 years period. The data set of total primary energy consumption (i.e., oil/ petroleum, gas; electricity and coal) is obtained from International Energy Outlook [44]. The series of balance of payment (BOP) factors (i.e., exports, imports, trade deficit, worker's remittances and current account balance), agricultural crops yield per hectare (i.e., wheat, rice, sugarcane, maize and cotton) and industrial production items (i.e., beverages, cigarettes, motor tyres, motor tubes, cycle tyres and cycle tubes) are taken from GoP [32]. The series of fuel factors (i.e., carbon dioxide emissions, natural resource depletion and net forest depletion) are taken from *World Development Indicators* published by the World Bank [95]. The total commercial energy consumption is used as the energy consumption indicators; balance of payment factors is used as the foreign sector; fuel factors is used as the environmental indicator; agricultural crops yield per capita and industrial production items are used as economic indicators, hence, as agriculture and industry modernizes, energy demand increases [101].

All these variables are expressed in natural logarithm and hence their first differences approximate their growth rates. The data trends are available for ready reference in Fig. 2.

All the variables seen in Table 5 were expected to have positive impact on the components of total primary energy consumption and other macro factors (i.e., BOP, fuel, agriculture and industrial) separately, since an increase in production assumes the use of more resource and energy.

Fig. 3 shows progress in energy factors which determines the association and causality between commercial energy consumption and macro-economic factors.

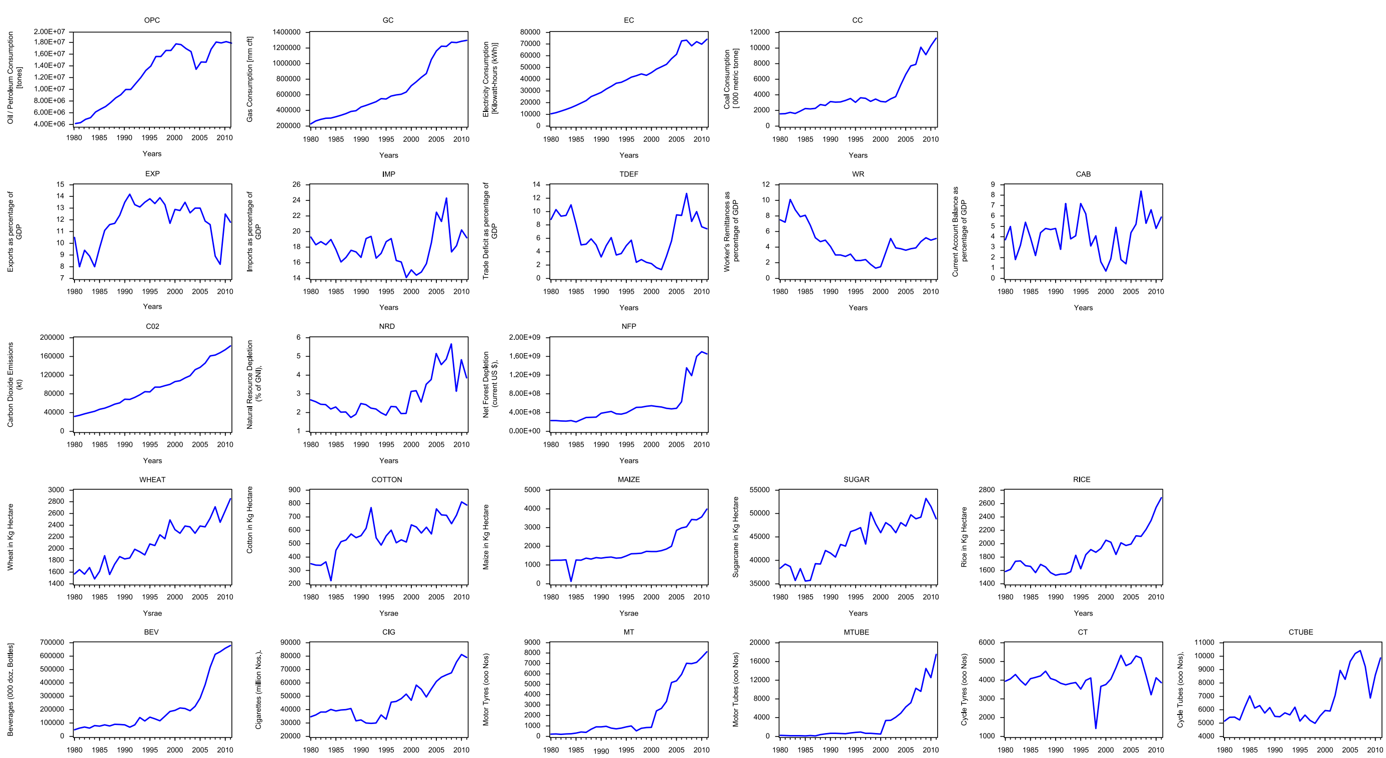

Fig. 2. Data trends for total primary energy consumption, BOP, fuel, agricultural crops yield per hectare and industrial factors.
Source: Refs. [44,95, 32].

Table 5
Variables in the equations and expected sign.

Variables	Measurement	Definition	Expected sign	Data source
Oil/petroleum consumption (OPC)	Ton	Petroleum or crude oil is a naturally occurring flammable liquid consisting of a complex mixture of hydrocarbons of various molecular weights and other liquid organic compounds that are found in geologic formations beneath the Earth's surface		[44]
Gas consumption (GC)	Millimeter cubic foot (mm cft)	Natural gas is a naturally occurring hydrocarbon gas mixture consisting primarily of methane, with other hydrocarbons, carbon dioxide, nitrogen and hydrogen sulfide. Natural gas is an important energy source to provide heating and electricity. It is also used as fuel for vehicles and as a chemical feedstock in the manufacture of plastics and other commercially important organic chemicals		[44]
Electricity consumption (EC)	Kilo Watt per hour (kwh)	Electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants		[44]
Coal consumption (CC)	000 metric ton	Coal is composed primarily of carbon along with variable quantities of other elements, chiefly hydrogen, sulfur, oxygen, and nitrogen		International Energy outlook [44]
BOP factors				
Exports (EXP)	As percentage of GDP	Exports of goods and services represent the value of all goods and other market services provided to the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal and government services. They exclude compensation of employees and investment income (formerly called factor services) and transfer payments	Positive	[32]
Imports (IMP)	As percentage of GDP	Imports of goods and services represent the value of all goods and other market services received from the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal and government services. They exclude compensation of employees and investment income (formerly called factor services) and transfer payments	Positive	[32]
Trade deficit (TDEF)	As percentage of GDP	It is the difference between the monetary value of exports and imports of output in an economy over a certain period	Positive	[32]
Workers' remittances (WR)	As percentage of GDP	Workers' remittances and compensation of employees comprise current transfers by migrant workers and wages and salaries earned by nonresident workers	Positive	[32]
Current account balance (CAB)	As percentage of GDP	It is the sum of the balance of trade (i.e., net earnings on exports minus payments for imports), factor income (earnings on foreign investments minus payments made to foreign investors) and cash transfers	Positive	[32]
FUEL factors				
Carbon dioxide emissions (CO_2)	Kiloton (kt)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid and gas fuels and gas flaring	Positive	[95]
Natural resources depletion (NRD)	% of GNI	Natural resource depletion is the sum of net forest depletion, energy depletion and mineral depletion	Positive	[95]
Net forest depletion (NFD)	Current US $	Net forest depletion is unit resource rents times the excess of round-wood harvest over natural growth	Positive	[95]
Agricultural crops yield per hectare (AGRI)				
Wheat (WHEAT)	kg hectare	Wheat is the leading source of vegetable protein in human food, having higher protein content than either maize (corn) or rice, the other major cereals	Positive	[32]
Rice (RICE)	kg ha	Rice is a cereal grain; it is the most important staple food for a large part of the world's human population	Positive	[32]
Sugarcane (SUGURE)	kg ha	Sugarcane belongs to the grass family (Poaceae), an economically important seed plant family that includes maize, wheat, rice, and sorghum and many forage crops. The main product of sugarcane is sucrose, which accumulates in the stalk internodes	Positive	[32]

Table 5 (*continued*)

Variables	Measurement	Definition	Expected sign	Data source
Maize (MAIZE)	kg ha	Maize is a grain	Positive	[32]
Cotton (COTTON)	kg ha	Cotton is a soft, fluffy staple fiber	Positive	[32]
Industrial production items (IND)				
Beverages (BEV)	000 doz. bottles	A drink, or beverage, is a liquid which is specifically prepared for human consumption	Positive	[32]
Cigarettes (CIG)	Million nos.	The term cigarette, as commonly used, refers to a tobacco cigarette but can apply to similar devices containing other herbs, such as cloves or cannabis	Positive	[32]
Motor tyres (MT)	000 nos.	Motorcycle tyres provide the only contact with the ground, via the contact patch under normal conditions, and so have a very large influence over motorcycle handling characteristics	Positive	[32]
Motor tubes (MTUBE)	000 nos.	A motorcycle fork connects a motorcycle's front wheel and axle to its frame, typically via a pair of triple clamps. It typically incorporates the front suspension and front brake, and allows the bike to be steered via handlebars attached to the top clamp	Positive	[32]
Cycle tyres (CT)	000 nos.	A bicycle tire is a tire that fits on the wheel of a bicycle, unicycle, tricycle, quadracycle, bicycle trailer, or trailer bike. They may also be used on wheelchairs and handcycles, especially for racing. Bicycle tires provide an important source of suspension, generate the lateral forces necessary for balancing and turning, and generate the longitudinal forces necessary for propulsion and braking	Positive	[32]
Cycle tubes (CTUBE)	000 nos.	A bicycle frame is the main component of a bicycle, on to which wheels and other components are fitted. The modern and most common frame design for an upright bicycle is based on the safety bicycle, and consists of two triangles, a main triangle and a paired rear triangle. This is known as the diamond frame	Positive	[32]

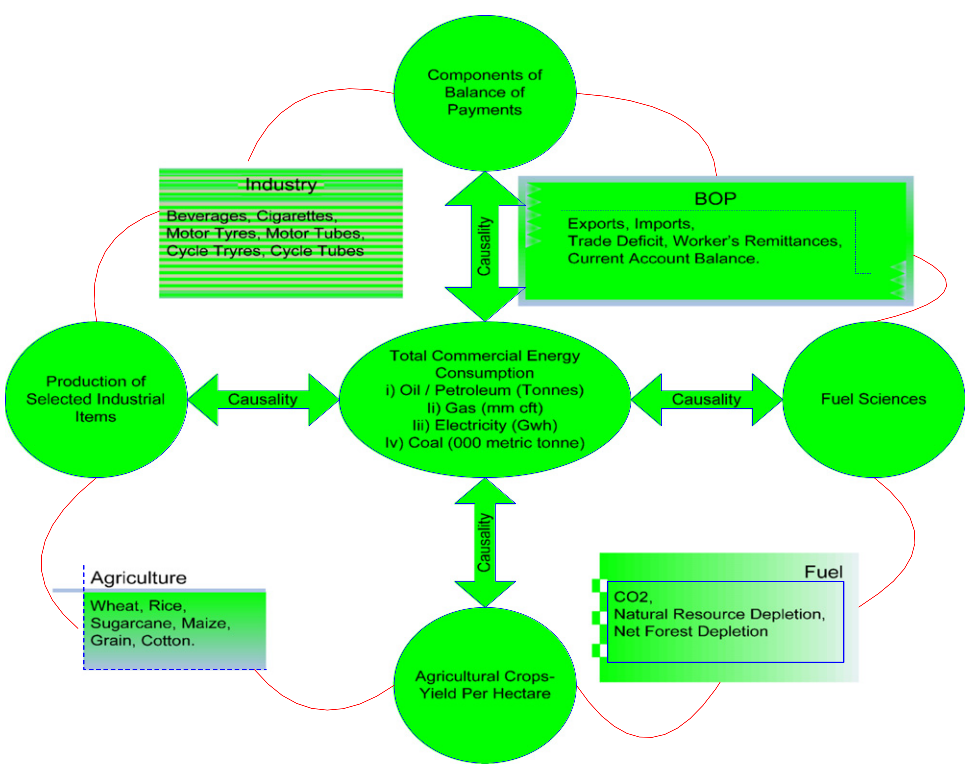

Fig. 3. Progress in energy.
Source: Self extract.

4.1. Econometric procedure

The impact of total commercial energy consumption factors on macro-economic factors are examined separately in the following manners:

- By examining whether a time series have a unit root test; an Augmented Dickey-Fuller (ADF) unit root test has been used.
- By finding the long-run relationship among the variable, Engle and Granger cointegration test has been applied.
- When the variables are found cointegrated, an error correction model (ECM) has been applied to determine the short-run dynamics of the system.
- Finally, Granger causality test has been implied to determine the causality between the variables.

4.1.1. Cointegration test

The concept of cointegration was first introduced by Granger [35] and elaborated further by Engle and Granger [25], Philips and Ouliaris [73] and Johansen [50], among others. Engle and Granger cointegration test requires that

- Time-series, say Y_t and X_t, are non-stationary in levels but stationary in first differences, i.e., $Y_t \sim I(1)$ and $X_t \sim I(1)$. The first step for cointegration is to test whether each of the series are stationary or not. If both variables are stationary, say at first difference, i.e., they are I(1),[1] then we may go to the second step to verify the long-run relationship between them.
- There exists a linear combination between these two series that is stationary at levels, i.e., $\nu_{it}(=Y_t-\alpha\hat{}-\beta\hat{}X_t)\sim I(0)$. For long-run relationship, $I(1)$ series of Y_t and X_t are said to be cointegrated, if the residual series, ν_{it} is stationary in levels, $I(0)$.

Augmented Dickey Fuller (ADF) test is usually applied to test stationarity. It tests the null hypothesis that a series (Y_t) is non-stationary by calculating a t-statistics for $\beta=0$ in the following equation:

$$\Delta Y_t=\alpha+\beta Y_{t-1}+\gamma_t+\sum_{k=2}^{n}\delta_k \Delta Y_{t-k}+\varepsilon_t$$

where k=2, 3, …, n. While α,β,γ and δ are the parameters to be estimated and ε_t is white noise error term.

If the value of the ADF statistic is less than the critical value at the conventional significance level (usually the 5% significance level) then the series (Y_t) is said to be stationary and vice versa. If Y_t is found to be non-stationary then it should be determined whether Y_t is stationary at first differences $\Delta Y_t \sim I(1)$ by repeating the above procedure. If the first difference of the series is stationary then the series (Y_t) may be concluded as integrated of order one, i.e., $Y_t \sim I(1)$.

4.1.2. Error correction model (ECM)

If time series are $I(1)$, then regressions could be run in their first differences. However, by taking first differences, the long-run relationship will be lost that is stored in the data. This implies to use variables in levels as well. Advantage of the error correction model (ECM) is that it incorporates variables both in their levels and first differences. By doing this, ECM captures the short-run disequilibrium situations as well as the long-run equilibrium adjustments between variables. ECM term having negative sign and value between "0 and 1" indicates convergence of model towards long-run equilibrium and shows how much percentage adjustment takes place every year.

4.1.3. Granger causality test

If a pair of series is cointegrated then there must be Granger causality in at least one direction, which reflects the direction of influence between series. Theoretically, if the current or lagged terms of a time series variables, say X_t, determine another time-series variable, say Y_t, then there exists a Granger causality relationship between X_t and Y_t, in which Y_t is granger caused by X_t.

5. Results and discussions

Economic time-series data are often found to be non-stationary, containing a unit root. Ordinary least squares (OLS) estimates are efficient if variables included in the model are stationary of the same order. Therefore, first we need to check the stationarity of all variables, i.e., OPC, GC, EC, CC, EXP, IMP, TDEF, WR, CAB, WHEAT, RICE, SUGAR, MAIZE, COTTON, BEV, CIG, MT, MTUBE, CT and CTUBE used in the study. For this purpose we apply Augmented Dickey-Fuller (ADF) test. Table 6 gives the results of ADF tests.

Based on the ADF test, the result reveals that all variables appear to be non-stationary at levels but stationary at their first difference. Thus, we may conclude that these variables are integrated of order one, i.e., I (1). Fig. 4 shows the plots of total commercial energy consumption and macro-economic factors in their first difference forms, which sets the analytical framework as regarding the long-term relationship between them.

The cointegration test between energy and macro-economic factors are carried out separately. After finding the series of $I(1)$, the results of regression and ADF test for the residual is being estimated for all four models separately. The results are presented from Tables 7–10, respectively. The regression results of Table 7 for Model-1 reveal that if there is 1% increase in oil/petroleum consumption (OPC), exports increases by 0.195%, fuel factors [i.e., carbon dioxide emission (CO_2), natural resource depletion (NRD), net forest depletion (NFD)] increases by 1.019%, 0.300% and 1.038%, respectively, agriculture yield per hectare (i.e., wheat, rice, maize, sugar and rice) increases by 0.350%, 0.471%, 0.735%, 0.218% and 0.213%, respectively, and industrial items [i.e., beverages (BEV), cigarettes (CIG), motor tyres (MT), motor tubes (MTUBE) and cycle tubes (CTUBE)] increases by 1.320%, 0.396%, 2.086%, 2.715%, 0.220%, respectively. The result indicates that export expansion increases the demand for the factors of production (capital, labor, energy) used to make the exports. Once exports are produced, machinery and equipment must be used to load and transport the exports to seaports, airports or other docking stations where the exports are then offloaded and reloaded for voyages abroad. The machinery and equipment used in the production, processing and transportation of goods for export require energy to operate. An increase in exports represents an increase in economic activity in export oriented sectors and this should increase the demand for energy [76]. On the other hand, there is a negative relationship between OPC and trade deficit along with worker's remittances in Pakistan. The result implies that energy consumption have a variety of aggregate impacts on the economy. The macroeconomic effects include government accounts, the balance of payments, the long-run growth potential of the economy, and the degree of energy intensity of capital investment [94]. The adjusted R-square was in the range of 12.4–87.9%, respectively. F-value is higher than its critical value

[1] $I(1)$ represent a non stationary series in levels but it becomes stationary after differencing once.

Table 6
Augmented Dickey-Fuller (ADF) test on the levels and on the first difference of the variables (1980–2011).

Variables	Level	First differences	Mackinnon critical values for rejection of hypothesis of a unit root			Decision
			I%	5%	10%	
Oil/petroleum consumption (OPC)	1.931(0)	−2.057** (2)	−2.634	−1.952	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Gas consumption (GC)	2.629(5)	−2.351**(0)	−2.634	−1.951	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Electricity consumption (EC)	2.827(0)	−2.481**(1)	−2.634	−1.951	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Coal consumption (CC)	2.412(2)	−2.012**(2)	−2.634	−1.951	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Exports (EXP)	−0.131(0)	−6.500*(0)	−2.634	−1.951	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Imports (IMP)	−0.314(0)	−6.672*(0)	−2.634	−1.951	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Trade deficit (TDEF)	−0.933(0)	−6.167*(0)	−2.634	−1.951	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Workers' remittances (WR)	−1.091(0)	−5.151*(0)	−2.634	−1.951	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Current account balance (CAB)	−1.150(0)	−8.106*(0)	−2.634	−1.951	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Carbon dioxide emissions (CO_2)	2.461(0)	−5.757*(0)	−2.634	−1.951	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Natural resources depletion (NRD)	0.404(1)	−9.505*(0)	−2.634	−1.951	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Net forest depletion (NFD)	1.707(0)	−5.662*(0)	−2.634	−1.952	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Wheat (WHEAT)	3.741(2)	−8.146*(0)	−2.634	−1.952	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Rice (RICE)	1.915(0)	−5.860*(0)	−2.634	−1.952	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Sugarcane (SUGAR)	1.882(2)	−8.189*(0)	−2.634	−1.952	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Maize (MAIZE)	1.413(0)	−2.452*(2)	−2.634	−1.952	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Cotton (COTTON)	0.414(0)	−4.342*(2)	−2.634	−1.952	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Beverages (BEV)	3.285(4)	−2.346**(0)	−2.634	−1.952	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Cigarettes (CIG)	1.737(0)	−5.933*(0)	−2.634	−1.952	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Motor tyres (MT)	1.345(2)	−2.981*(1)	−2.634	−1.952	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Motor tubes (MTUBE)	2.597(1)	−4.245*(2)	−2.634	−1.952	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Cycle tyres (CT)	−0.372(1)	−7.830*(0)	−2.634	−1.952	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)
Cycle tubes (CTUBE)	0.666(0)	−5.326*(0)	−2.634	−1.952	−1.610	Non-stationary at level but stationary at first difference, i.e., *I* (1)

Note: The null hypothesis is that the series is non-stationary, or contains a unit root. The rejection of the null hypothesis is based on MacKinnon critical values. The lag length are selected based on SIC criteria, this ranges from lag zero to lag one. The statistics significant at 1% and 5% level of significance is indicated by * and **.

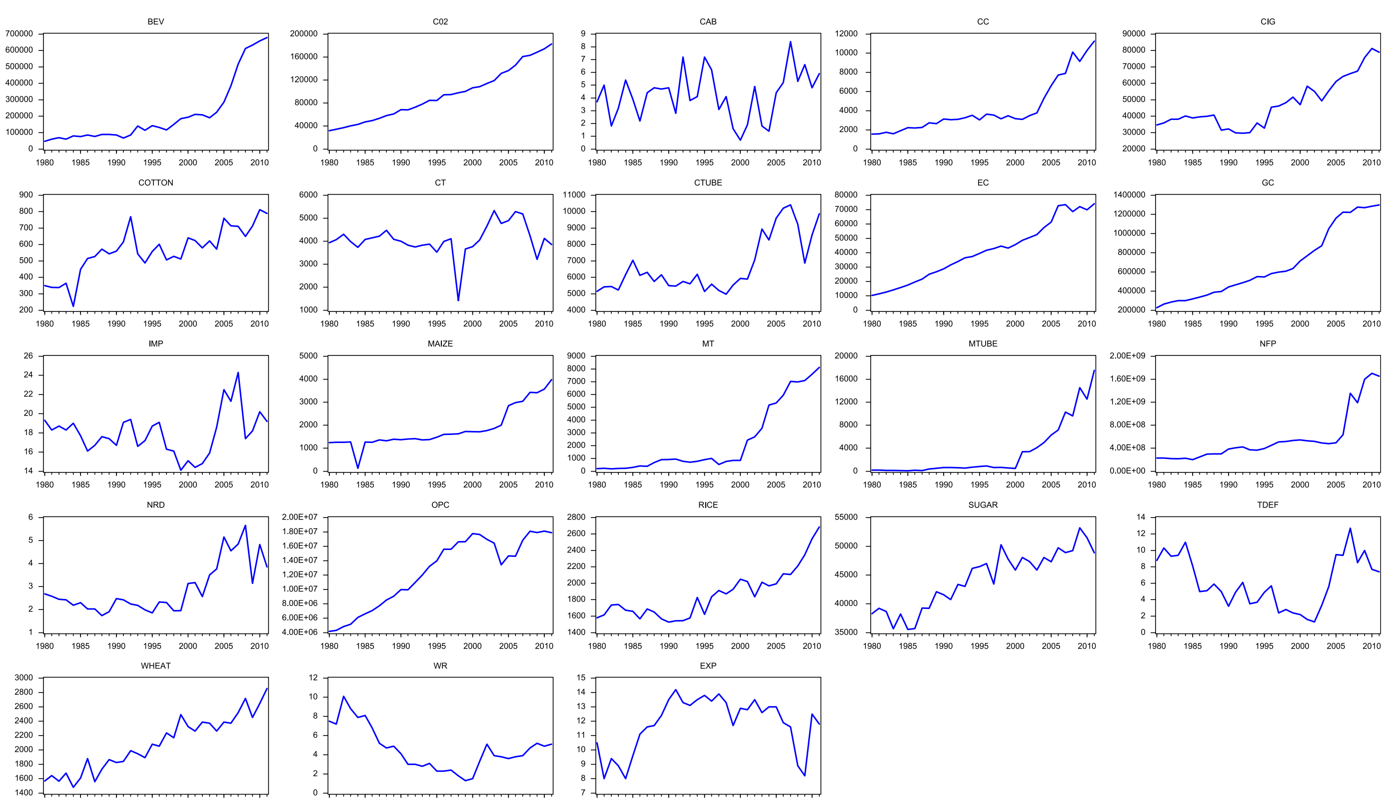

Fig. 4. Data trends for total primary energy consumption, BOP, fuel, agricultural crops yield per hectare and industrial factors at first difference.
Source: International Energy Outlook (2011), WDI (2011) and GoP (2012).

suggesting a good overall significance of the estimated model. Therefore, fitness of the model-1 is acceptable empirically. Our empirical results indicate a long-run relationship among industrial production, oil consumption and fuel factors. This could be explained by the fact that oil is a significant input in industrial production [104].

Table 7
Empirical results of the model-oil/petroleum consumption (1980–2011).

Model 1: Oil/petroleum consumption (OPC)						
	Balance of payment (BOP) factors					
	Log (EXP)	Log (IMP)	Log (TDEF)	Log (WR)	Log (CAB)	
Constant	−0.723	3.392*	10.368*	13.471*	0.448	
Log (OPC)	0.195*	−0.031	−0.535*	−0.743*	0.053	
AR(1)	0.620*	0.623*	0.794*	0.851*	0.612*	
Adjusted *R*-square	0.531	0.346	0.647	0.787	0.124	
Durbin-Watson	1.716	1.946	1.869	1.418	1.996	
F-statistics	18.037*	8.945	28.548*	56.560**	3.400**	
	Fuel factors					
	Log (CO_2)	Log (NRD)	Log (NFD)			
Constant	−5.232*	−3.873**	3.073			
Log (OPC)	1.019*	0.300*	1.038*			
AR(1)	0.979*	0.753*	1.031*			
Adjusted *R*-square	0.879	0.650	0.635*			
Durbin-Watson	2.012	2.269	2.084			
F-statistics	226.631*	28.829*	54.914*			
	Agricultural crops yield per hectare					
	Log (WHEAT)	Log (COTTON)	Log (MAIZE)	Log (SUGAR)	Log (RICE)	
Constant	1.931*	−1.363	−4.546	7.138*	4.056*	
Log (OPC)	0.350*	0.471*	0.735*	0.218*	0.213*	
AR(1)	0.441**	0.390**	0.401**	0.388**	0.999*	
Adjusted *R*-square	0.803	0.595*	0.325	0.794	0.831	
Durbin-Watson	2.190	1.980	1.583	2.211	1.992	
F-statistics	127.981*	46.564*	15.965*	120.801*	24.979*	
	Industrial items					
	Log (BEV)	Log (CIG)	Log (MT)	Log (MUTUBE)	Log (CT)	Log(CTUBE)
Constant	−9.509*	4.276*	−26.833*	−37.203*	8.817	5.208*
Log (OPC)	1.320*	0.396*	2.086*	2.715*	−0.032	0.220*
AR(1)	0.999*	0.979*	0.974*	0.993*	0.442**	0.856*
Adjusted *R*-square	0.624	0.871	0.603	0.610	0.389	0.713
Durbin-Watson	2.177	1.992	2.017	2.012	1.551	1.856
F-statistics	52.583*	19.343*	53.845*	49.491*	4.812*	7.633*

Table 8
Empirical results of the model—gas consumption (1980–2011).

Model 11: Gas consumption (GC)					
	Balance of payment (BOP) factors				
	Log (EXP)	Log (IMP)	Log (TDEF)	Log (WR)	Log (CAB)
Constant	1.721	1.615	−7.093	6.167	−0.293
Log (GC)	0.055	0.094	0.641	−0.358**	0.121
AR(1)	0.715*	0.607*	0.833*	0.914*	0.384**
Adjusted *R*-square	0.509	0.571	0.650	0.794	0.515
Durbin-Watson	1.817	2.004	1.937	1.487	1.902
F-statistics	16.595*	9.876*	28.972*	59.032*	2.525
	Fuel factors				
	Log (CO_2)	Log (NRD)	Log (NFD)		
Constant	−1.105*	−5.126*	6.407*		
Log (GC)	0.936	0.461*	1.019*		
AR(1)	0.973*	0.539*	0.750*		
Adjusted *R*-square	0.975	0.545	0.810		
Durbin-Watson	2.125	2.012	1.657		
F-statistics	1247.985*	38.213*	133.165*		
	Agricultural crops yield per hectare				
	Log (WHEAT)	Log (COTTON)	Log (MAIZE)	Log (SUGAR)	Log (RICE)
Constant	3.387*	0.871	−3.783	8.102*	3.283**
Log (GC)	0.319*	0.409*	0.840*	0.194*	0.318*
AR(1)	0.712*	0.592**	0.689*	0.511**	0.771*
Adjusted *R*-square	0.876	0.627	0.514	0.821	0.847
Durbin-Watson	1.990	2.044	2.056	2.129	2.142
F-statistics	220.537*	26.243*	16.895*	70.153*	84.247*

Table 8 (*continued*)

	Industrial items					
	Log (BEV)	Log (CIG)	Log (MT)	Log (MUTUBE)	Log (CT)	Log(MTUBE)
Constant	−7.197**	2.131	−23.560*	−34.772*	7.498	4.154*
Log (GC)	1.440*	0.642*	2.302*	3.133*	0.059	0.322*
AR(1)	0.718*	0.814*	0.618*	0.434*	0.401**	0.741*
Adjusted *R*-square	0.874	0.889	0.956	0.941	0.527	0.551
Durbin-Watson	1.926	2.144	1.978	2.125	1.576	1.892
F-statistics	259.845*	122.289*	328.285*	242.721*	0.547	39.124*

Table 9
Empirical results of the model—electricity consumption (1980–2011).

Model 111: Electricity consumption (EC)						
	Balance of payment (BOP) factors					
	Log (EXP)	Log (IMP)	Log (TDEF)	Log (WR)	Log (CAB)	
Constant	1.076**	2.685*	−18.838	−1.588	−0.337	
Log (EC)	0.131*	0.018	1.841	−0.471*	0.157	
AR(1)	0.671*	0.641*	0.903*	0.887*	0.388**	
Adjusted *R*-square	0.523	0.368	0.656	0.785	0.156	
Durbin-Watson	1.801	2.021	2.017	1.433	1.910	
F-statistics	17.497*	9.755*	29.655*	56.321	2.601	
	Fuel factors					
	Log (CO_2)	Log (NRD)	Log (NFD)			
Constant	12.196*	−2.504*	5.615			
Log (EC)	0.860*	0.334*	1.356**			
AR(1)	0.983*	0.639*	0.811*			
Adjusted *R*-square	0.981	0.654	0.921			
Durbin-Watson	1.825	2.011	1.766			
F-statistics	1638.256*	16.216*	177.102*			
	Agricultural crops yield per hectare					
	Log (WHEAT)	Log (COTTON)	Log (MAIZE)	Log (SUGAR)	Log (RICE)	
Constant	4.418*	1.954**	−0.576	8.662*	4.743*	
Log (EC)	0.306*	0.415*	0.759*	0.193*	0.264	
AR(1)	0.589*	0.612*	0.741*	0.339***	0.824*	
Adjusted *R*-square	0.859	0.668*	0.560	0.847	0.822	
Durbin-Watson	2.070	1.986	2.062	2.161	2.166	
F-statistics	93.139*	31.213*	13.796*	84.330*	70.352*	
	Industrial items					
	Log (BEV)	Log (CIG)	Log (MT)	Log (MUTUBE)	Log (CT)	Log(MTUBE)
Constant	−3.744	4.972	−19.445*	−31.716*	8.075*	5.578*
Log (EC)	1.490**	0.543***	2.511*	3.663*	0.020	0.306
AR(1)	0.862*	0.850*	0.808*	0.752*	0.652*	0.768*
Adjusted *R*-square	0.943	0.870	0.952	0.936	0.325	0.720
Durbin-Watson	1.844	2.206	2.012	2.135	2.001	2.060
F-statistics	252.432*	102.035*	300.791*	221.736*	0.777	39.582*

The empirical results, given in Table 8, model-11, appear to be very good in terms of the usual diagnostic statistics. The value of adjusted *R*-square indicates that more than 50% variation in dependent variable has been explained by variations in independent variable. *F*-value is higher than its critical value, suggesting a good overall significance of the estimated model. Therefore, fitness of the model is acceptable empirically. The Durbin Watson Test statistics shows that autocorrelation does not appear to be a problem. The result suggests that if there is 1% increase in gas consumption, natural resource depletion increases by 0.461%, net forest depletion increases by 1.019%, agriculture yield per hectare (wheat, cotton, maize, sugar, rice) increases by 0.319%, 0.409%, 0.840%, 0.194% and 0.318%, respectively, and industrial items [(i.e., beverages (BEV), cigarettes (CIG), motor tyres (MT), motor tubes (MTUBE) and cycle tubes (CTUBE)] increases by 1.440%, 0.642%, 2.302%, 3.133% and 0.322%, respectively. On the other side, gas consumption decreases worker's remittances (WR) by 0.358%. The remaining variables are found to be insignificant. The result shows that the relationship between energy and exports are neutral. The correlation between energy consumption and exports is so small that it does not show up as a statistically significant relationship at conventional test levels. On the other

Table 10
Empirical results of the model—coal consumption (1980–2011).

Model 1V: Coal consumption (CC)						
	Balance of payment (BOP) factors					
	Log (EXP)	Log (IMP)	Log (TDEF)	Log (WR)	Log (CAB)	
Constant	2.346**	2.166*	−1.349	−0.608	−0.935	
Log (CC)	0.014	0.085	0.352	0.226	0.274	
AR(1)	0.728*	0.550*	0.794*	0.880*	0.335***	
Adjusted R-square	0.507	0.380	0.651*	0.790	0.121	
Durbin-Watson	1.839*	2.024	1.958	1.384	1.912	
F-statistics	16.481*	10.207*	29.070*	57.478*	3.072***	
	Fuel factors					
	Log (CO_2)	Log (NRD)	Log (NFD)			
Constant	11.600*	−2.959*	12.505*			
Log (CC)	0.143*	0.479*	0.909*			
AR(1)	0.967*	0.557*	0.561			
Adjusted R-square	0.996	0.709	0.894			
Durbin-Watson	2.012	2.300	1.946			
F-statistics	4873.254*	37.715*	128.813*			
	Agricultural crops yield per hectare					
	Log (WHEAT)	Log (COTTON)	Log (MAIZE)	Log (SUGAR)	Log (RICE)	
Constant	5.691*	3.451*	0.888	10.446*	5.856*	
Log (CC)	0.237*	0.349*	0.794*	0.033	0.204*	
AR(1)	0.609*	0.364**	0.596*	0.839*	0.771*	
Adjusted R-square	0.815	0.603	0.522	0.774	0.840	
Durbin-Watson	2.371	2.0.87	2.051	2.104	2.030	
F-statistics	67.511*	23.861*	17.385*	52.447	80.062*	
	Industrial items					
	Log (BEV)	Log (CIG)	Log (MT)	Log (MUTUBE)	Log (CT)	Log(MTUBE)
Constant	18.960	7.604*	−513.912	404.215	7.756*	6.087*
Log (CC)	0.189	0.382**	0.122	−0.153	0.065	0.329*
AR(1)	0.991*	0.853*	0.895*	0.989*	0.597*	0.687*
Adjusted R-square	0.946	0.822	0.945	0.914	0.127	0.767
Durbin-Watson	2.198	1.903	2.210	2.014	2.029	1.925
F-statistics	268.512*	123.518*	260.351*	161.801*	1.012	50.561*

side, increasing the energy efficiency of motor vehicles (carbon emissions) is critical to achieving national energy goals of reduced petroleum dependence, protecting the global climate and promoting continued economic prosperity. Even in the presence of fuel economy and greenhouse gas emissions standards and various economic incentives for clean efficient vehicles, providing reliable and accurate fuel economy information to the public is important to the efficient functioning of the marketplace [36].

The empirical result, given in Table 9 (model-111), shows that exports have a positive while worker's remittances have a negative relationship with the electricity consumption. However, other factors, i.e., fuel factors; agricultural crops yield per hectare and industrial items have a positive relationship with the electricity consumption in Pakistan. The result implies that electricity consumption enabled agricultural users to access electricity at prices below the marginal cost of supply, thereby lowering the cost of irrigation and groundwater extraction, an essential input in agricultural production. This electricity consumption may also generate economic inefficiencies. They may distort decisions over electricity consumption and groundwater extraction and induce individuals to grow more water intensive crops (Badiani and Jessoe, 2011). Rural people were traditionally not dependent on commercial sources of energy. Most of their needs for crop production, animal-raising and domestic activities were met by renewable sources of energy such as fuel-wood and the products, by-products and residues of crop production and animal-raising systems [81]. "Energizing" the food production chain has been an essential feature of agricultural development and it is a prime factor in helping to achieve food security. Developing countries have lagged behind industrialized countries in modernizing their energy inputs to agriculture. An energy input is required in food processing, as well as in packaging, distribution and storage. Many food crops when harvested cannot be consumed directly, but must pass through several stages of processing as well as cooking in order to be palatable and digestible. Raw meats, uncooked grains, vegetables and even fruits require preparation and heating to enhance their flavor, rendering their components edible and digestible. The processing and cooking stages reduce harmful organisms and parasites, which might pose health hazards [26]. Our empirical results indicate a long-run relationship among industrial production, electricity consumption and agricultural crops yield per hectare. This result is not surprising, since industrial energy consumption accounts for up to 63% of total electricity consumption [104].

In Table 10, Model IV shows that there is no relationship between BOP factors and coal consumption (CC); however, fuel factors, agriculture yield per hectare and most of industrial items have a positive and significant relationship with coal consumption in Pakistan. Coal is the major element for the industrial revolution. The environmental consequences of the sustained use of coal have drawn into question of long-term viability of coal in light of the emergence of cleaner and alternative energy sources [8]. The result concludes the positive impact of an increase in coal consumption on agriculture and industrial production may be attributed to the efficient use of coal as well as

Table 11
Augmented Dickey-Fuller test for the residuals.

Variables	Level	Mackinnon critical values for rejection of hypothesis of a unit root			Decision
		I%	5%	10%	
Model 1: Oil/petroleum consumption (OPC)					
Exports (EXP)	−5.285*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Imports (IMP)	−9.859*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Trade deficit (TDEF)	−6.678*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Workers' remittances (WR)	−4.428*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Current account balance (CAB)	−7.789*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Carbon dioxide emissions (CO_2)	−4.235*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Natural resources depletion (NRD)	−6.395*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Net forest depletion (NFD)	−7.245*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Wheat (WHEAT)	−7.812*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Rice (RICE)	−8.012*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Sugarcane (SUGAR)	−6.286*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Maize (MAIZE)	−7.779*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cotton (COTTON)	−7.625*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Beverages (BEV)	−6.698*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cigarettes (CIG)	−4.362*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Motor tyres (MT)	−3.895*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Motor tubes (MTUBE)	−3.021*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cycle tyres (CT)	−4.025*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cycle tubes (CTUBE)	−2.912*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Model 11: Gas consumption (GC)					
Exports (EXP)	−4.428*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Imports (IMP)	−3.326*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Trade deficit (TDEF)	−9.958*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Workers' remittances (WR)	−2.523**	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Current account balance (CAB)	−2.969*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Carbon dioxide emissions (CO_2)	−0.759*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Natural resources depletion (NRD)	−6.625*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Net forest depletion (NFD)	−1.895***	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Wheat (WHEAT)	−11.254*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Rice (RICE)	−6.669*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Sugarcane (SUGAR)	−4.489*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Maize (MAIZE)	−7.285*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cotton (COTTON)	−6.699*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Beverages (BEV)	−9.998*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cigarettes (CIG)	−2.285*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Motor Tyres (MT)	−7.859*	−2.634	−1.952	−1.610	Stationary at level i.e. I(0)
Motor tubes (MTUBE)	−8.012*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cycle tyres (CT)	−6.699*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cycle tubes (CTUBE)	−3.696*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Model 111: Electricity consumption (EC)					
Exports (EXP)	−7.775*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Imports (IMP)	−6.601*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Trade deficit (TDEF)	−6.698*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Workers' remittances (WR)	−4.442*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Current account balance (CAB)	−2.212**	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Carbon dioxide emissions (CO_2)	−7.771*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Natural resources depletion (NRD)	−6.985*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Net forest depletion (NFD)	−4.402*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Wheat (WHEAT)	−2.989*	−2.634	−1.952	−1.610	Stationary at level i.e. I(0)
Rice (RICE)	−7.698*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Sugarcane (SUGAR)	−11.253*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Maize (MAIZE)	−4.525*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cotton (COTTON)	−7.774*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Beverages (BEV)	−6.636*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cigarettes (CIG)	−4.410*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Motor tyres (MT)	−5.528*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Motor tubes (MTUBE)	−3.663*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cycle tyres (CT)	−8.589*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cycle tubes (CTUBE)	−9.996*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Model 1V: Coal consumption (CC)					
Exports (EXP)	−3.336*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Imports (IMP)	−9.858*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Trade deficit (TDEF)	−6.699*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Workers' remittances (WR)	−6.698*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Current account balance (CAB)	−4.440*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Carbon dioxide emissions (CO_2)	−5.012*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Natural resources depletion (NRD)	−6.620*	−2.634	−1.951	−1.610	Stationary at level, i.e., *I*(0)
Net forest depletion (NFD)	−3.336*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Wheat (WHEAT)	−4.412*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)

Table 11 (*continued*)

Variables	Level	Mackinnon critical values for rejection of hypothesis of a unit root			Decision
		I%	5%	10%	
Rice (RICE)	−11.215*	−2.634	−1.952	−1.610	Stationary at level i.e. I(0)
Sugarcane (SUGAR)	−4.443*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Maize (MAIZE)	−6.612*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cotton (COTTON)	−7.714*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Beverages (BEV)	−8.011*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cigarettes (CIG)	−6.996*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Motor tyres (MT)	−8.858*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Motor tubes (MTUBE)	−4.589*	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cycle tyres (CT)	−1.781***	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)
Cycle tubes (CTUBE)	−2.258**	−2.634	−1.952	−1.610	Stationary at level, i.e., *I*(0)

Note: The statistics significant at 1%, 5% and 10 level of significance is indicated by *, ** and ***.

Table 12
Empirical results of error correction model—oil/petroleum consumption (1980–2011).

Model 1: Oil/petroleum consumption (OPC)					
	Balance of payment (BOP) factors				
	Log (EXP)	Log (IMP)	Log (TDEF)	Log (WR)	Log (CAB)
Constant	1.217*	2.012*	0.812	0.012	−0.425
Log (OPC)	0.425	0.174	0.615	−0.125**	0.012
ρ	−0.045*	−0.125*	−0.351**	−0.025	−0.145**
Adjusted *R*-square	0.521	0.621	0.714	0.127	0.654
Durbin-Watson	2.012	1.842	2.002	1.241	2.036
F-statistics	124.253*	78.214*	29.635?*	7.689*	1245.325*
	Fuel factors				
	Log (CO_2)	Log (NRD)	Log (NFD)		
Constant	0.158	1.859	4.529*		
Log (OPC)	0.235*	0.485*	0.174**		
ρ	−0.845*	−0.687*	−0.114**		
Adjusted *R*-square	0.684	0.891	0.660		
Durbin-Watson	2.002	1.898	1.748		
F-statistics	14.285*	17.289*	8.214*		
	Agricultural crops yield per hectare				
	Log (WHEAT)	Log (COTTON)	Log (MAIZE)	Log (SUGAR)	Log (RICE)
Constant	0.824	1.012	1.485	−2.852***	−4.524*
Log (OPC)	1.125*	0.874*	0.662*	0.012	0.489
ρ	−0.582*	−0.062	−0.824*	−0.002	−0.147
Adjusted *R*-square	0.898	0.602	0.584	0.325	0.125
Durbin-Watson	2.012	1.848	1.989	1.451	1.124
F-statistics	16.689*	14.258*	12.213*	6.253*	1.258
	Industrial items				
	Log (BEV)	Log (CIG)	Log (MT)	Log (MUTUBE)	Log (CT)
Constant	−0.625	−0.125	2.254*	4.859*	−2.124
Log (OPC)	0.023	0.814*	0.026**	0.124	0.824*
ρ	−0.925*	−0.225**	−0.852*	0.024	0.154
Adjusted *R*-square	0.625	0.458	0.858	0.127	0.235
Durbin-Watson	2.001	1.584	1.742	1.625	1.528
F-statistics	234.256*	12.358*	23.569*	1.928	2.012

the possibility that the immediate economic benefit of the use of coal on agriculture and industrial production may be outweighed by the economic costs imposed on the environment by carbon dioxide emissions. Furthermore, greater use of sustainable coal technologies that permit carbon dioxide capture and storage may reduce the environmental costs on the economy of excessive coal consumption [9]. There is a modest long-run relationship exist in models involving coal consumption and industrial production. This could be explained by the fact that coal is not used directly in the production process but to generate electricity which is then used by the industry [20].

The finding for Table 11 reveals that the residual is stationary at level that is it is integrated of order zero. This authenticates our intention that macro-economic factors and commercial energy consumption factors are indeed cointegrated, that is a long-run relationship between them holds.

In order to ensure stability of long-run relationship between commercial energy consumption factors and macro-economic

Table 13
Empirical results of error correction model—gas consumption **(1980–2011).**

Model-11: Gas consumption (GC)

Balance of payment (BOP) factors	Log (EXP)	Log (IMP)	Log (TDEF)	Log (WR)	Log (CAB)	
Constant	1.589*	2.184*	0.625	−0.212	−0.895	
Log (GC)	0.802	0.258	0.525	−0.525**	0.112	
ρ	−0.445*	−0.489*	−0.451**	−0.225*	−0.245**	
Adjusted R-square	0.612	0.521	0.614	0.227	0.564	
Durbin-Watson	2.025	1.742	2.085	1.891	2.036	
F-statistics	12.259*	7.555*	9.352*	17.896*	125.895*	
Fuel factors	Log (CO_2)	Log (NRD)	Log (NFD)			
Constant	2.569*	4.522*	1.892**			
Log (GC)	0.414*	1.201*	1.020*			
ρ	−0.596*	−0.898*	−0.125**			
Adjusted R-square	0.689	0.852	0.546			
Durbin-Watson	2.001	1.958	1.689			
F-statistics	12.356*	19.325*	22.369*			
Agricultural crops yield per hectare	Log (WHEAT)	Log (COTTON)	Log (MAIZE)	Log (SUGAR)	Log (RICE)	
Constant	−0.259	−0.589	−1.892	9.658*	4.569*	
Log (GC)	−0.256*	−0.465*	2.125*	1.895*	0.965**	
ρ	−0.568*	−0.898*	−0.659*	−0.356*	−0.012	
Adjusted R-square	0.859	0.568	0.789	0.523	0.658	
Durbin-Watson	1.589	1.698	1.586	1.689	1.258	
F-statistics	123.569*	15.256*	18.965	8.025*	3.259**	
Industrial items	Log (BEV)	Log (CIG)	Log (MT)	Log (MUTUBE)	Log (CT)	Log(CTUBE)
Constant	−6.963*	−6.369*	−5.236*	−0.002	−0.125	0.023
Log (GC)	1.235*	0.986*	0.523*	−0.256**	−0.459*	0.214
ρ	−0.526*	−0.569*	−0.235*	−0.259*	−0.895*	−0.002
Adjusted R-square	0.625	0.721	0.523	0.857	0.625	0.014
Durbin-Watson	1.895	1.685	1.778	1.485	1.658	1.712
F-statistics	121.254*	17.859*	12.854*	28.235*	16.626*	2.985**

Table 14
Empirical results of error correction model—electricity consumption (1980–2011).

Model-111: Electricity consumption (EC)

Balance of payment (BOP) factors	Log (EXP)	Log (IMP)	Log (TDEF)	Log (WR)	Log (CAB)
Constant	2.356	1.853	−2.457*	−1.158**	−0.002
Log (EC)	0.882*	0.445**	0.898*	−0.254**	0.125
ρ	−0.625*	−0.147**	−0.235*	−0.012	−0.875*
Adjusted R-square	0.828	0.625	0.525	0.458	0.689
Durbin-Watson	1.859	1.552	1.789	1.958	1.698
F-statistics	12.859*	19.986*	28.596*	7.825*	18.285*
Fuel factors	Log (CO_2)	Log (NRD)	Log (NFD)		
Constant	1.258*	2.256*	4.525*		
Log (EC)	1.254*	0.895*	0.459*		
ρ	−0.689*	−0.459*	−0.669*		
Adjusted R-square	0.689	0.785	0.857		
Durbin-Watson	1.895	1.669	1.852		
F-statistics	12.654*	11.859*	29.998*		
Agricultural crops yield per hectare	Log (WHEAT)	Log (COTTON)	Log (MAIZE)	Log (SUGAR)	Log (RICE)
Constant	−1.447	−4.236	−1.001	−1.669	4.895*
Log (EC)	1.225*	0.669*	−0.412**	−0.825*	−1.012*
ρ	−0.395*	−0.859*	−0.142**	−0.356*	−0.012
Adjusted R-square	0.901	0.971	0.621	0.782	0.458
Durbin-Watson	1.990	2.031	1.990	2.002	1.958
F-statistics	129.235*	78.252*	18.289*	29.359*	7.289*

Table 14 (*continued*)

	Industrial items					
	Log (BEV)	Log (CIG)	Log (MT)	Log (MUTUBE)	Log (CT)	Log(MTUBE)
Constant	−0.289	−1.200	3.212*	2.001*	0.065	0.213
Log (EC)	0.895*	0.214*	−0.859*	1.112*	0.550**	0.412***
ρ	−0.289*	−0.125***	−0.448*	−0.989*	−0.045**	−0.142*
Adjusted *R*-square	0.662	0.428	0.501	0.665	0.445	0.612
Durbin-Watson	1.898	1.445	1.668	1.720	1.823	1.714
F-statistics	11.248*	3.001**	5.025*	8.001*	5.969*	6.012*

Table 15
Empirical results of error correction model—coal consumption (1980–2011).

Model 1V: Coal consumption (CC)						
	Balance of payment (BOP) factors					
	Log (EXP)	Log (IMP)	Log (TDEF)	Log (WR)	Log (CAB)	
Constant	0.012	−1.285*	−2.258*	−1.852*	−4.223*	
Log (CC)	−0.485*	−0.698*	0.142	−0.478*	1.012*	
ρ	−0.859*	−0.147*	0.214	−0.289*	−0.457*	
Adjusted *R*-square	0.661	0.589	0.341	0.418	0.660	
Durbin-Watson	2.012	2.253	1.414	1.695	1.895	
F-statistics	15.968*	7.012*	2.612***	4.998*	6.969*	
	Fuel factors					
	Log (CO_2)	Log (NRD)	Log (NFD)			
Constant	−2.212*	−1.898*	−0.696**			
Log (CC)	0.478*	0.669*	0.142**			
ρ	−0.696*	−0.852*	−0.421*			
Adjusted *R*-square	0.714	0.612	0.714			
Durbin-Watson	1.898	1.698	1.885			
F-statistics	21.365*	11.254*	12.585*			
	Agricultural crops yield per hectare					
	Log (WHEAT)	Log (COTTON)	Log (MAIZE)	Log (SUGAR)	Log (RICE)	
Constant	0.213	−1.285*	−2.121*	−1.452*	0.785	
Log (CC)	−0.412*	−0.665*	−0.125	0.742**	−0.412*	
ρ	−0.854*	−0.400*	−0.162	−0.337*	−0.658*	
Adjusted R-square	0.852	0.661	0.348	0.825	0.885	
Durbin-Watson	1.844	1.712	1.412	1.669	2.023	
F-statistics	19.632*	11.256*	4.991*	7.989*	6.369*	
	Industrial items					
	Log (BEV)	Log (CIG)	Log (MT)	Log (MUTUBE)	Log (CT)	Log(MTUBE)
Constant	−2.012*	−1.025*	−0.898**	0.742	0.668	−0.124*
Log (CC)	0.845*	0.568*	0.148**	0.658*	0.142	0.412*
ρ	−0.414*	−0.285*	−0.689*	0.102	−0.458*	−0.145*
Adjusted R-square	0.612	0.589	0.785	0.124	0.525	0.852
Durbin-Watson	2.002	2.142	2.012	1.124	2.012	1.625
F-statistics	12.356*	14.256*	16.012*	7.285*	14.258*	5.259*

factors, an error correction model (ECM) has been used. The results are presented in Table 12.

The finding reveals that the short-run effect and the long-run adjustment impact between the commercial energy consumption and macro-economic factors are significant at 1%, 5% and 10% level, respectively. The adjustment parameter (p) for model-1 appears with negative value signifying the long-run convergence. The ECM estimation reveals that ranges between 2.5% and 35.1% of the disequilibrium in BOP factors, between 11.4% and 84.5% in fuel factors, ranges from 6.2% to 82.4% in agricultural factors and 2.4% to 92.5% disequilibrium in industrial items produced by oil/petroleum consumption (OPC) would be adjusted in every year.

For Table 13, model-11, the adjustment parameter (p) shows the long-run convergence as adjustment parameter (p) appears with negative value. The ECM estimation reveals that ranges from 22.5% to 48.9% disequilibrium in BOP, ranges between 12.5% and 89.8% in fuel factors, ranges between 1.2% and 89.8% and ranges from 23.5% to 89.5% of the disequilibrium produced by gas consumption (GC) would be adjusted in every year.

In Table 14, model-111, the adjustment parameter (p) shows the long-run convergence as adjustment parameter (p) appears with negative value. The ECM estimation reveals that ranges from 14.7% to 87.5% disequilibrium in BOP, ranges between 45.9% and 68.9% in fuel factors, ranges between 14.2% and 85.9% and ranges

Table 16
Causality patterns—oil/petroleum consumption.

Lagged years	Null hypothesis	Decision
Model 1: Oil/petroleum consumption (OPC) and balance of payments factors		
	Exports (EXP)	
1	No causality from Log (OPC) to Log (EXP)	Accepted
	No causality from Log (EXP) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (EXP)	Accepted
	No causality from Log (EXP) to Log (OPC)	Accepted
	Imports (IMP)	
1	No causality from Log (OPC) to Log (IMP)	**Rejected**
	No causality from Log (IMP) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (IMP)	**Rejected**
	No causality from Log (IMP) to Log (OPC)	Accepted
	Trade deficit (TDEF)	
1	No causality from Log (OPC) to Log (TDEF)	**Rejected**
	No causality from Log (TDEF) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (TDEF)	**Rejected**
	No causality from Log (TDEF) to Log (OPC)	Accepted
	Worker's remittances (WR)	
1	No causality from Log (OPC) to Log (WR)	Accepted
	No causality from Log (WR) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (WR)	Accepted
	No causality from Log (WR) to Log (OPC)	Accepted
	Current account deficit (CAD)	
1	No causality from Log (OPC) to Log (CAD)	Accepted
	No causality from Log (CAD) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (CAD)	Accepted
	No causality from Log (CAD) to Log (OPC)	Accepted
Oil/petroleum consumption (OPC) and fuel factors		
	Carbon dioxide emissions (CO_2)	
1	No causality from Log (OPC) to Log (CO_2)	**Rejected**
	No causality from Log (CO_2) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (CO_2)	**Rejected**
	No causality from Log (CO_2) to Log (OPC)	Accepted
	Natural resource depletion (NRD)	
1	No causality from Log (OPC) to Log (NRD)	**Rejected**
	No causality from Log (NRD) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (NRD)	**Rejected**
	No causality from Log (NRD) to Log (OPC)	Accepted
	Net forest depletion (NFD)	
1	No causality from Log (OPC) to Log (NFD)	**Rejected**
	No causality from Log (NFD) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (NFD)	**Rejected**
	No causality from Log (NFD) to Log (OPC)	Accepted
Oil/petroleum consumption (OPC) and agriculture yield per capita		
	WHEAT	
1	No causality from Log (OPC) to Log (WHEAT)	**Rejected**
	No causality from Log (WHEAT) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (WHEAT)	**Rejected**
	No causality from Log (WHEAT) to Log (OPC)	Accepted
	COTTON	
1	No causality from Log (OPC) to Log (COTTON)	**Rejected**
	No causality from Log (COTTON) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (COTTON)	**Rejected**
	No causality from Log (COTTON) to Log (OPC)	Accepted
	MAIZE	
1	No causality from Log (OPC) to Log (MAZIE)	**Rejected**
	No causality from Log (MAIZE) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (MAIZE)	**Rejected**
	No causality from Log (MAZIE) to Log (OPC)	Accepted
	Sugarcane (CUGAR)	
1	No causality from Log (OPC) to Log (SUGAR)	**Rejected**
	No causality from Log (SUGAR) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (SUGAR)	**Rejected**
	No causality from Log (SUGAR) to Log (OPC)	Accepted
	RICE	
1	No causality from Log (OPC) to Log (RICE)	**Rejected**
	No causality from Log (RICE) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (RICE)	**Rejected**
	No causality from Log (RICE) to Log (OPC)	Accepted
Oil/petroleum consumption (OPC) and industrial items		
	Beverages (BEV)	
1	No causality from Log (OPC) to Log (BEV)	**Rejected**
	No causality from Log (RICE) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (BEV)	**Rejected**
	No causality from Log (RICE) to Log (OPC)	Accepted
	Cigarettes (CIG)	
1	No causality from Log (OPC) to Log (CIG)	**Rejected**
	No causality from Log (CIG) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (CIG)	**Rejected**
	No causality from Log (CIG) to Log (OPC)	Accepted
	Motor tyres (MT)	
1	No causality from Log (OPC) to Log (MT)	Accepted
	No causality from Log (MT) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (MT)	Accepted
	No causality from Log (MT) to Log (OPC)	Accepted
	Motor tubes (MTUBE)	
1	No causality from Log (OPC) to Log (MTUBE)	Accepted
	No causality from Log (MTUBE) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (MTUBE)	Accepted
	No causality from Log (MTUBE) to Log (OPC)	Accepted
	Cycle tyres (CT)	
1	No causality from Log (OPC) to Log (CT)	Accepted
	No causality from Log (CT) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (CT)	Accepted
	No causality from Log (CT) to Log (OPC)	Accepted
	Cycle tubes (CTUBE)	
1	No causality from Log (OPC) to Log (CTUBE)	Accepted
	No causality from Log (CTUBE) to Log (OPC)	Accepted
2	No causality from Log (OPC) to Log (CTUBE)	Accepted
	No causality from Log (CTUBE) to Log (OPC)	Accepted

from 45.1% to 98.9% of the disequilibrium produced by electricity consumption (EC) would be adjusted in every year. Result further shows that imported goods affect the demand for energy. Imports are trade flows into a country and this require a well function transportation network to move goods around. Transportation requires energy and increases in trade flows are expected to increase energy consumption. The composition of imports affects energy consumption especially when the imports are energy intensive products like automobiles, dishwashers, air conditioners, etc. It is possible that energy consumption affects the flow of imported goods especially when the imported goods are machinery or equipment that requires energy to operate. The importance of electricity consumption for Pakistan may analyze with the report of Pakistan Energy Year Book, 2009, i.e., electricity is a major source of energy in the industrial and agriculture sectors and together these two sectors contributed almost 50% of Pakistan's GDP. The share of industrial, agriculture and commercial sectors in electricity consumption is 27.5%, 12.5% and 7.5%, respectively. At the same time, the contribution of industrial, agriculture and services sectors to GDP is 24.26%, 21.55% and 54.18%, respectively. These statistics show that these sectors contributed significantly to GDP and electricity consumption. Hence, it is clear that electricity consumption does play an important role in GDP of Pakistan through the contribution of these three sectors. Energy conservation policies or lack of accessible energy reduce the usefulness and efficiency of energy dependent imported goods, making it less likely that such good will be imported [74].

In Table 15, model-1V, the adjustment parameter (p) shows the long-run convergence as adjustment parameter (p) appears with negative value. The ECM estimation reveals that ranges from 14.7% to 85.9% disequilibrium in BOP, ranges between 42.1% and 85.2% in fuel factors, ranges between 16.2% and 85.4% and ranges from 10.2% to 68.9% of the disequilibrium produced by coal consumption (CC) would be adjusted in every year. The result concludes that energy in the form of coal consumption is one of the most ubiquitous elements in modern industrial production systems. Energy services are embodied in all goods and services

Table 17
Causality patterns—gas consumption.

Lagged years	Null hypothesis	Decision
Model 1: Gas consumption (GC) and balance of payments factors		
	Exports (EXP)	
1	No causality from Log (GC) to Log (EXP)	**Rejected**
	No causality from Log (EXP) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (EXP)	**Rejected**
	No causality from Log (EXP) to Log (GC)	Accepted
	Imports (IMP)	
1	No causality from Log (GC) to Log (IMP)	**Rejected**
	No causality from Log (IMP) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (IMP)	**Rejected**
	No causality from Log (IMP) to Log (GC)	Accepted
	Trade deficit (TDEF)	
1	No causality from Log (GC) to Log (TDEF)	**Accepted**
	No causality from Log (TDEF) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (TDEF)	**Accepted**
	No causality from Log (TDEF) to Log (GC)	Accepted
	Worker's remittances (WR)	
1	No causality from Log (GC) to Log (WR)	Accepted
	No causality from Log (WR) to Log (GC)	**Accepted**
2	No causality from Log (GC) to Log (WR)	Accepted
	No causality from Log (WR) to Log (GC)	**Accepted**
	Current account deficit (CAD)	
1	No causality from Log (GC) to Log (CAD)	Accepted
	No causality from Log (CAD) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (CAD)	Accepted
	No causality from Log (CAD) to Log (GC)	Accepted
Gas consumption (GC) and fuel factors		
	Carbon dioxide emissions (CO_2)	
1	No causality from Log (GC) to Log (CO_2)	**Rejected**
	No causality from Log (CO_2) to Log (GC)	**Rejected**
2	No causality from Log (GC) to Log (CO_2)	**Rejected**
	No causality from Log (CO_2) to Log (GC)	**Rejected**
	Natural resource depletion (NRD)	
1	No causality from Log (GC) to Log (NRD)	**Rejected**
	No causality from Log (NRD) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (NRD)	**Rejected**
	No causality from Log (NRD) to Log (GC)	Accepted
	Net forest depletion (NFD)	
1	No causality from Log (GC) to Log (NFD)	**Rejected**
	No causality from Log (NFD) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (NFD)	**Rejected**
	No causality from Log (NFD) to Log (GC)	Accepted
Gas consumption (GC) and agriculture yield per capita		
	WHEAT	
1	No causality from Log (GC) to Log (WHEAT)	**Rejected**
	No causality from Log (WHEAT) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (WHEAT)	**Rejected**
	No causality from Log (WHEAT) to Log (GC)	Accepted
	COTTON	
1	No causality from Log (GC) to Log (COTTON)	Accepted
	No causality from Log (COTTON) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (COTTON)	Accepted
	No causality from Log (COTTON) to Log (GC)	Accepted
	MAIZE	
1	No causality from Log (GC) to Log (MAZIE)	**Rejected**
	No causality from Log (MAIZE) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (MAIZE)	**Rejected**
	No causality from Log (MAZIE) to Log (GC)	Accepted
	Sugarcane (CUGAR)	
1	No causality from Log (GC) to Log (SUGAR)	**Rejected**
	No causality from Log (SUGAR) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (SUGAR)	**Rejected**
	No causality from Log (SUGAR) to Log (GC)	Accepted
	RICE	
1	No causality from Log (GC) to Log (RICE)	Accepted
	No causality from Log (RICE) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (RICE)	Accepted
	No causality from Log (RICE) to Log (GC)	Accepted
Gas consumption (GC) and industrial items		
	Beverages (BEV)	
1	No causality from Log (GC) to Log (BEV)	Accepted
	No causality from Log (RICE) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (BEV)	Accepted
	No causality from Log (RICE) to Log (GC)	Accepted
	Cigarettes (CIG)	
1	No causality from Log (GC) to Log (CIG)	**Rejected**
	No causality from Log (CIG) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (CIG)	**Rejected**
	No causality from Log (CIG) to Log (GC)	Accepted
	Motor tyres (MT)	
1	No causality from Log (GC) to Log (MT)	Accepted
	No causality from Log (MT) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (MT)	Accepted
	No causality from Log (MT) to Log (GC)	Accepted
	Motor tubes (MTUBE)	
1	No causality from Log (GC) to Log (MTUBE)	Accepted
	No causality from Log (MTUBE) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (MTUBE)	Accepted
	No causality from Log (MTUBE) to Log (GC)	Accepted
	Cycle tyres (CT)	
1	No causality from Log (GC) to Log (CT)	Accepted
	No causality from Log (CT) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (CT)	Accepted
	No causality from Log (CT) to Log (GC)	Accepted
	Cycle tubes (CTUBE)	
1	No causality from Log (GC) to Log (CTUBE)	**Rejected**
	No causality from Log (CTUBE) to Log (GC)	Accepted
2	No causality from Log (GC) to Log (CTUBE)	**Rejected**
	No causality from Log (CTUBE) to Log (GC)	Accepted

through both direct and indirect energy consumption. Direct energy consumption refers to the energy used directly in the process of producing a good or service. Indirect energy consumption refers to the energy embodied in intermediate goods and services used throughout a production process. Elucidating direct and indirect energy linkages across supply chains requires detailed information about inter-industry transactions and careful accounting for energy's contribution at every stage of production, from resource extraction to final consumption [52]. The conclusion is that there is a stable long-run relationship between all of them.

To confirm the causal relationship between the commercial energy consumption factors and macro-economic factors, a Granger causality test has been applied using lag length up to two periods. The following four hypotheses are tested.

i. Commercial energy consumption (i.e., OPC, GC, EC and CC factors) Grange causes economic factors (i.e., BOP, fuel, agriculture and industrial factors).
ii. Economic factors Granger causes commercial energy consumption factors.
iii. Causality runs in both directions.
iv. Commercial energy consumption factors and economic factors are independent.

The result of Table 16 shows that "OPC does not Granger cause EXP, WR, CAD, MT, MTUBE, CT and CTUBE" and "EXP, WR, CAD, MT, MTUBE, CT and CTUBE does not Granger cause OPC" both are accepted at both legs. This supports our forth hypothesis, i.e., oil/petroleum consumption (OPC) and EXP, WR, CAD, MT, MTUBE, CT and CTUBE are independent in nature and they have no causality exist between them. However, there has been unidirectional causality running from OPC to IMP, OPC to TDEF, OPC to FUEL factors (CO_2, NRD, NFD), OPC to agriculture yield per hectare (wheat, cotton, maize, sugar and rice), OPC to BEV and OPC to CIG, respectively. This confirms our first hypothesis, i.e., causality runs towards commercial energy consumption factors to economic factors but not vice versa.

Table 18
Causality patterns—electricity consumption.

Lagged years	Null hypothesis	Decision
Model 1: Electricity consumption (EC) and balance of payments factors		
	Exports (EXP)	
1	No causality from Log (EC) to Log (EXP)	**Rejected**
	No causality from Log (EXP) to Log (EC)	**Rejected**
2	No causality from Log (EC) to Log (EXP)	**Rejected**
	No causality from Log (EXP) to Log (EC)	**Rejected**
	Imports (IMP)	
1	No causality from Log (EC) to Log (IMP)	**Rejected**
	No causality from Log (IMP) to Log (EC)	**Rejected**
2	No causality from Log (EC) to Log (IMP)	**Rejected**
	No causality from Log (IMP) to Log (EC)	**Rejected**
	Trade deficit (TDEF)	
1	No causality from Log (EC) to Log (TDEF)	**Rejected**
	No causality from Log (TDEF) to Log (EC)	Accepted
2	No causality from Log (EC) to Log (TDEF)	**Rejected**
	No causality from Log (TDEF) to Log (EC)	Accepted
	Worker's remittances (WR)	
1	No causality from Log (EC) to Log (WR)	Accepted
	No causality from Log (WR) to Log (EC)	**Rejected**
2	No causality from Log (EC) to Log (WR)	Accepted
	No causality from Log (WR) to Log (EC)	**Rejected**
	Current account deficit (CAD)	
1	No causality from Log (EC) to Log (CAD)	**Rejected**
	No causality from Log (CAD) to Log (EC)	Accepted
2	No causality from Log (EC) to Log (CAD)	**Rejected**
	No causality from Log (CAD) to Log (EC)	Accepted
Electricity consumption (EC) and fuel factors		
	Carbon dioxide emissions (CO_2)	
1	No causality from Log (EC) to Log (CO_2)	**Rejected**
	No causality from Log (CO_2) to Log (EC)	**Rejected**
2	No causality from Log (EC) to Log (CO_2)	**Rejected**
	No causality from Log (CO_2) to Log (EC)	**Rejected**
	Natural resource depletion (NRD)	
1	No causality from Log (EC) to Log (NRD)	**Rejected**
	No causality from Log (NRD) to Log (EC)	**Rejected**
2	No causality from Log (EC) to Log (NRD)	**Rejected**
	No causality from Log (NRD) to Log (EC)	**Rejected**
	Net forest depletion (NFD)	
1	No causality from Log (EC) to Log (NFD)	**Rejected**
	No causality from Log (NFD) to Log (EC)	Accepted
2	No causality from Log (EC) to Log (NFD)	**Rejected**
	No causality from Log (NFD) to Log (EC)	Accepted
Electricity consumption (EC) and agriculture yield per capita		
	WHEAT	
1	No causality from Log (EC) to Log (WHEAT)	**Rejected**
	No causality from Log (WHEAT) to Log (EC)	**Rejected**
2	No causality from Log (EC) to Log (WHEAT)	**Rejected**
	No causality from Log (WHEAT) to Log (EC)	**Rejected**
	COTTON	
1	No causality from Log (EC) to Log (COTTON)	**Rejected**
	No causality from Log (COTTON) to Log (EC)	Accepted
2	No causality from Log (EC) to Log (COTTON)	**Rejected**
	No causality from Log (COTTON) to Log (EC)	Accepted
	MAIZE	
1	No causality from Log (EC) to Log (MAZIE)	**Rejected**
	No causality from Log (MAIZE) to Log (EC)	Accepted
2	No causality from Log (EC) to Log (MAIZE)	**Rejected**
	No causality from Log (MAZIE) to Log (EC)	Accepted
	Sugarcane (CUGAR)	
1	No causality from Log (EC) to Log (SUGAR)	Accepted
	No causality from Log (SUGAR) to Log (EC)	**Rejected**
2	No causality from Log (EC) to Log (SUGAR)	Accepted
	No causality from Log (SUGAR) to Log (EC)	**Rejected**
	RICE	
1	No causality from Log (EC) to Log (RICE)	**Rejected**
	No causality from Log (RICE) to Log (EC)	Accepted
2	No causality from Log (EC) to Log (RICE)	**Rejected**
	No causality from Log (RICE) to Log (EC)	Accepted
Electricity consumption (EC) and industrial items		
	Beverages (BEV)	
1	No causality from Log (EC) to Log (BEV)	**Rejected**
	No causality from Log (BEV) to Log (EC)	Accepted
2	No causality from Log (EC) to Log (BEV)	**Rejected**
	No causality from Log (BEV) to Log (EC)	Accepted
	Cigarettes (CIG)	
1	No causality from Log (EC) to Log (CIG)	**Rejected**
	No causality from Log (CIG) to Log (EC)	Accepted
2	No causality from Log (EC) to Log (CIG)	**Rejected**
	No causality from Log (CIG) to Log (EC)	Accepted
	Motor tyres (MT)	
1	No causality from Log (EC) to Log (MT)	Accepted
	No causality from Log (MT) to Log (EC)	Accepted
2	No causality from Log (EC) to Log (MT)	Accepted
	No causality from Log (MT) to Log (EC)	Accepted
	Motor tubes (MTUBE)	
1	No causality from Log (EC) to Log (MTUBE)	Accepted
	No causality from Log (MTUBE) to Log (EC)	Accepted
2	No causality from Log (EC) to Log (MTUBE)	Accepted
	No causality from Log (MTUBE) to Log (EC)	Accepted
	Cycle tyres (CT)	
1	No causality from Log (EC) to Log (CT)	Accepted
	No causality from Log (CT) to Log (EC)	Accepted
2	No causality from Log (EC) to Log (CT)	Accepted
	No causality from Log (CT) to Log (EC)	Accepted
	Cycle tubes (CTUBE)	
1	No causality from Log (EC) to Log (CTUBE)	**Rejected**
	No causality from Log (CTUBE) to Log (EC)	Accepted
2	No causality from Log (EC) to Log (CTUBE)	**Rejected**
	No causality from Log (CTUBE) to Log (EC)	Accepted

The result of Table 17 shows that "GC does not Granger cause TDEF, WR, CAD, COTTON, RICE, BEV, MT, MTUBE, CT" and "TDEF, WR, CAD, COTTON, RICE, BEV, MT, MTUBE, CT does not Granger cause GC" both are accepted at first and second legs. This supports our fourth hypothesis, i.e., GC and TDEF, WR, CAD, COTTON, RICE, BEV, MT, MTUBE, CT are independent in nature. While there has been unidirectional causality running from GC to EXP, IMP, NRD, NFD, WHEAT, MAIZE, SUGAR, CIG and CTUBE, respectively.

The Granger causality patterns for electricity consumption shown in Table 18. The result shows that "EC does not Granger cause MT, MTUBE and CT" and "MT, MTUBE and CT does not Granger cause EC" both are accepted at first and second legs. This supports our fourth hypothesis, i.e., EC and MT, MTUBE and CT are independent in nature. While, there has been unidirectional causality running from EC to TDEF, CAD, NFD, COTTON, MAIZE, RICE, BEV, CIG and CTUBE", respectively, but not other way around this causality exist between them. The result further shows the bidirectional causality running between EC to EXP, EC to IMP, EC to CO_2, EC to NRD and EC to WHEAT. This does accord with the third hypothesis, i.e., causality runs in both directions. Exports cause energy use implying that energy saving policies has no adverse impact on export growth. On the other hand, energy consumption causes exports, implying that reduction in energy use limit expansion in exports which are considered to be engine of economic growth [38].

Subsequently, WR causes EC and SUGAR Granger cause EC confirms the second hypothesis, i.e., causality runs from economic factors to energy consumption but not vice versa.

The Granger causality patterns for coal consumption (CC) are shown in Table 19. The result shows that "CC does not Granger cause IMP, WR, CAD, MTUBE and CT" and "IMP, WR, CAD, MTUBE and CT does not Granger cause CC" both are accepted at first and second legs. This shows that causality between the variables is independent in nature. While, there has been unidirectional causality running from CC to EXP, TDEF, NFD, WHEAT, COTTON, MAIZE, RICE, BEV, CIG, MT and CTUBE", respectively, but not other way around this causality exist between them. The bidirectional causality running between CC to CO_2 and CC to NRD, which shows

Table 19
Causality patterns—coal consumption.

Lagged years	Null hypothesis	Decision
Model 1: Coal consumption (CC) and balance of payments factors		
	Exports (EXP)	
1	No causality from Log (CC) to Log (EXP)	**Rejected**
	No causality from Log (EXP) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (EXP)	**Rejected**
	No causality from Log (EXP) to Log (CC)	Accepted
	Imports (IMP)	
1	No causality from Log (CC) to Log (IMP)	Accepted
	No causality from Log (IMP) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (IMP)	Accepted
	No causality from Log (IMP) to Log (CC)	Accepted
	Trade deficit (TDEF)	
1	No causality from Log (CC) to Log (TDEF)	**Rejected**
	No causality from Log (TDEF) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (TDEF)	**Rejected**
	No causality from Log (TDEF) to Log (CC)	Accepted
	Worker's remittances (WR)	
1	No causality from Log (CC) to Log (WR)	Accepted
	No causality from Log (WR) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (WR)	Accepted
	No causality from Log (WR) to Log (CC)	Accepted
	Current account deficit (CAD)	
1	No causality from Log (CC) to Log (CAD)	Accepted
	No causality from Log (CAD) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (CAD)	Accepted
	No causality from Log (CAD) to Log (CC)	Accepted
Coal consumption (CC) and fuel factors		
	Carbon dioxide emissions (CO_2)	
1	No causality from Log (CC) to Log (CO_2)	**Rejected**
	No causality from Log (CO_2) to Log (CC)	**Rejected**
2	No causality from Log (CC) to Log (CO_2)	**Rejected**
	No causality from Log (CO_2) to Log (CC)	**Rejected**
	Natural resource depletion (NRD)	
1	No causality from Log (CC) to Log (NRD)	**Rejected**
	No causality from Log (NRD) to Log (CC)	**Rejected**
2	No causality from Log (CC) to Log (NRD)	**Rejected**
	No causality from Log (NRD) to Log (CC)	**Rejected**
	Net forest depletion (NFD)	
1	No causality from Log (CC) to Log (NFD)	**Rejected**
	No causality from Log (NFD) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (NFD)	**Rejected**
	No causality from Log (NFD) to Log (CC)	Accepted
Coal consumption (CC) and agriculture yield per capita		
	WHEAT	
1	No causality from Log (CC) to Log (WHEAT)	**Rejected**
	No causality from Log (WHEAT) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (WHEAT)	**Rejected**
	No causality from Log (WHEAT) to Log (CC)	Accepted
	COTTON	
1	No causality from Log (CC) to Log (COTTON)	**Rejected**
	No causality from Log (COTTON) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (COTTON)	**Rejected**
	No causality from Log (COTTON) to Log (CC)	Accepted
	MAIZE	
1	No causality from Log (CC) to Log (MAZIE)	**Rejected**
	No causality from Log (MAIZE) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (MAIZE)	**Rejected**
	No causality from Log (MAZIE) to Log (CC)	Accepted
	Sugarcane (CUGAR)	
1	No causality from Log (CC) to Log (SUGAR)	Accepted
	No causality from Log (SUGAR) to Log (CC)	**Rejected**
2	No causality from Log (CC) to Log (SUGAR)	Accepted
	No causality from Log (SUGAR) to Log (CC)	**Rejected**
	RICE	
1	No causality from Log (CC) to Log (RICE)	**Rejected**
	No causality from Log (RICE) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (RICE)	**Rejected**
	No causality from Log (RICE) to Log (CC)	Accepted
Coal consumption (CC) and industrial items		
	Beverages (BEV)	
1	No causality from Log (CC) to Log (BEV)	**Rejected**
	No causality from Log (BEV) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (BEV)	**Rejected**
	No causality from Log (BEV) to Log (CC)	Accepted
	Cigarettes (CIG)	
1	No causality from Log (CC) to Log (CIG)	**Rejected**
	No causality from Log (CIG) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (CIG)	**Rejected**
	No causality from Log (CIG) to Log (CC)	Accepted
	Motor tyres (MT)	
1	No causality from Log (CC) to Log (MT)	**Rejected**
	No causality from Log (MT) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (MT)	**Rejected**
	No causality from Log (MT) to Log (CC)	Accepted
	Motor tubes (MTUBE)	
1	No causality from Log (CC) to Log (MTUBE)	Accepted
	No causality from Log (MTUBE) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (MTUBE)	Accepted
	No causality from Log (MTUBE) to Log (CC)	Accepted
	Cycle tyres (CT)	
1	No causality from Log (CC) to Log (CT)	Accepted
	No causality from Log (CT) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (CT)	Accepted
	No causality from Log (CT) to Log (CC)	Accepted
	Cycle tubes (CTUBE)	
1	No causality from Log (CC) to Log (CTUBE)	**Rejected**
	No causality from Log (CTUBE) to Log (CC)	Accepted
2	No causality from Log (CC) to Log (CTUBE)	**Rejected**
	No causality from Log (CTUBE) to Log (CC)	Accepted

that causality runs in both directions. SUGAR Granger cause CC in both legs shows the unidirectional causality runs between them but not other way around.

6. Summary and conclusion

The relationship between energy consumption and economic growth has been debated quite extensively in the literature, yet the direction of the causality relationship remains unresolved. The debate has focused on whether energy consumption causes economic growth or economic growth causes energy consumption, or whether a two-way relationship exists. From a policy viewpoint, the direction of causality between these variables has important implications [98,66,30].

The objective of this study is to empirically investigate a two-way statistical relationship between the total primary energy consumption and macroeconomic variables in the context of Pakistan. To recognize the relationship between the two variables, a time series, co-integration and Granger Causality Tests have been employed. Secondary data pertaining to Pakistan from 1980 to 2011 on energy consumption and macro factors (such as oil/petroleum consumption, gas consumption, electricity consumption, coal consumption, exports, imports, trade deficit, worker's remittances, and current account balance, carbon dioxide emissions, natural resource depletion, net forest depletion, wheat, rice, sugarcane, maize, cotton, beverages, cigarettes, motor tyres, motor tubes, cycle tyres and cycle tubes) has been used for analysis. The results of the Granger causality test between total commercial energy consumption and macroeconomics variables reveal that oil/petroleum consumption has a unidirectional causality running to imports, trade deficit, carbon emission, natural resource depletion, agricultural crops, beverages and cigarette. Gas consumption has a unidirectional causality running to exports, imports, trade deficit, natural resource depletion, net forest depletion, wheat, maize, sugar, cigarette and cycle tube, however, gas consumption has a bidirectional causality running to carbon dioxide emission. Workers' remittances have a

unidirectional causality running to gas consumption. There is a bidirectional causality running between electricity consumption and exports, imports, carbon emissions, natural resource depletion and wheat yield per hectare. However, there has been unidirectional causality running between trade deficit, current account deficit, natural resource depletion, cotton, maize, rice, beverages, cigarettes and cycle tubes. Workers' remittances and sugar Granger cause electricity consumption but not vice versa. Coal consumption Grange cause exports, trade deficit, net forest depletion, wheat, cotton, maize, rice beverages, cigarettes, motor tyres and cycle tubes. The result confirms the conventional view that casualty running to energy consumption to macroeconomic factors but not vice versa. However, coal consumption Granger cause carbon emissions and natural resource depletion which shows that the causality running in both directions. On the other hand, sugar production Granger cause coal consumption which shows unidirectional causality between them. Among the renewable energy sources, the energy derivatives of wheat, sugarcane, rice, maize, cotton, i.e., ethanol fuel and cogenerated electricity, experienced the higher growth rate during the evaluated period being the possible main beneficiaries the industrial, energy generation and transport sectors. Furthermore, the trend in aggregate CO_2 emissions suggests that economic activity and unstable pattern of energy intensity have partially offset the most of the expected benefits of carbon intensity reduction and an improved fuel mix [29]. Coal consumption (CC) also Granger cause CO_2 and NRD, which shows that there is also bidirectional causality exists between these variables. The results show that emissions change has been predominantly influenced by economic activity. It was observed that fuel diversification toward lower emissions sources and carbon intensity is amongst the factors that contributed to the deceleration of emissions growth for the period 1980–2011 in Pakistan.

The policy implication is that energy policy should orientate towards increasing supply of electricity to sustain economic growth [19]. Electricity can be treated as a potential fuel to replace petroleum products mainly in household and transportation sector [14]. The results of causality show a feedback relationship between balance of payment factors like exports and energy consumption and this has important implications for energy and environmental policy. One implication is that trade expansion policies like export promotion policies designed to increase exports will also increase energy consumption. This means that predictions of future energy consumption that do not take into account the effect of exports will likely underestimate the demand for energy. This could lead to demand shortages and supply interruptions if forward looking energy supply decisions are made assuming lower than actual energy consumption. Another implication is that environmental policies that reduce energy consumption will affect the growth in exports. This puts environmental policy aimed at reducing energy consumption at odds with trade policy. A better environmental approach is to facilitate a rise in energy consumption by increasing the share of renewable energy relative to non-renewable energy [76]. Sector specific policies such as the reduction of price support for arable production reduce the incentive to convert pasture land into arable production thereby reducing CO_2 losses from agricultural soils. Land diversion policies are expected to have some beneficial impacts in terms of increasing the potential for carbon sequestration, increasing the contribution of agriculture and forestry to energy supply and reducing applications of nitrogen fertilizers (reducing N_2O emissions). Specific measures to restrict production such as quotas on livestock production, and to reduce the use of fertilizer inputs such as the removal of subsidies for fertilizer use are also expected to reduce national GHG emissions [69].

Environmental impacts are the unwanted byproduct of economic activities. Inadvertently, humans alter environmental conditions such as the acidity of soils, the nutrient content of surface water, the radiation balance of the atmosphere and the concentrations of trace materials in food chains. Humans convert forest to pastureland and grassland to cropland or parking lots intentionally, but the resulting habitat change and biodiversity loss is still undesired [90]. Comprehensive policies to control vehicular carbon emissions, such as improving fuel economy, controlling vehicle numbers, encouraging the development of public transport (reducing the use of private cars) and reasonable urban transportation plans and constructions, should be considered simultaneously in Pakistani cities. The causality approach used above to analyze the relationship between energy consumption and macroeconomic factors provides a useful means of discriminating among the alternative hypotheses. The study suggests that only single equation/conventional method is insufficient to assess the strong relationship. Therefore, it is important to establish simultaneous equation/s for long-run relationship. This conclusion opens a new avenue for future researchers [97].

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